
Spring 1998
arnoldia
The Magazine of the Arnold Arboretum

arnoldia

Volume 58 Number 1 1998

Arnoldia (ISSN 004-2633; USPS 866-100) is published quarterly by the Arnold Arboretum of Harvard University. Second-class postage paid at Boston, Massachusetts.

Subscriptions are $20.00 per calendar year domestic, $25.00 foreign, payable in advance. Most single copies are $5.00. Remittances may be made in U.S. dollars, by check drawn on a U.S. bank; by international money order; or by Visa or Mastercard. Send orders, remittances, change-of-address notices, and all other subscription-related communications to: Circulation Manager, *Arnoldia*, The Arnold Arboretum, 125 Arborway, Jamaica Plain, Massachusetts 02130-3500. Telephone 617/524-1718; facsimile 617/524-1418; e-mail arnoldia@arnarb.harvard.edu.

Postmaster: Send address changes to
Arnoldia Circulation Manager
The Arnold Arboretum
125 Arborway
Jamaica Plain, MA 02130-3500

Karen Madsen, *Editor*
Andy Winther, *Designer*

Page

2 An Evolutionary Perspective on Strengths, Fallacies, and Confusions in the Concept of Native Plants
Stephen Jay Gould

11 E. D. Merrill, From Maine to Manila
Ida Hay

20 Light in a Bottle: Plant-Collecting in the Philippines
Rob Nicholson

27 The Ecology and Economics of Elm Replacement in Harvard Yard
Peter Del Tredici

Cover: For much of this century, a house and an American elm comprised the basic domestic landscape of eastern North America. Photograph by Peter Del Tredici.

Inside front cover: *Livistonia saribus*, the Livistone palm, named by E. D. Merrill, bears unusual bright-blue fruits. Photograph from the Archives of the Fairchild Tropical Garden.

Inside back cover: An American elm of classic, vase-shaped form photographed in the Montreal Botanic Garden by Peter Del Tredici.

Back cover: Elmer Drew Merrill, later Director of the Arnold Arboretum, in a detail of a 1902 photograph seen on page 12.

Erratum: In our last issue, Winter 1997-1998, volume 57, number 4, two numbers were inverted in the Arnold Arboretum Weather Station Data—1997. Last spring's last frost was a low of 29° on April 16.


PETER DEL TREDICI

An Evolutionary Perspective on Strengths, Fallacies, and Confusions in the Concept of Native Plants

Stephen Jay Gould

An important, but widely unappreciated, concept in evolutionary biology draws a clear and careful distinction between the historical origin and current utility of organic features. Feathers, for example, could not have originated for flight because five percent of a wing in the early intermediary stages between small running dinosaurs and birds could not have served any aerodynamic function (though feathers, derived from reptilian scales, provide important thermodynamic benefits right away). But feathers were later co-opted to keep birds aloft in a most exemplary fashion. In like manner, our large brains could not have evolved in order to permit modern descendants to read and write, though these much later functions now define an important part of modern utility.

Similarly, the later use of an argument, often in a context foreign or even opposite to the intent of originators, must be separated from the validity and purposes of initial formulations. Thus, for example, Darwin's theory of natural selection is not diminished because later racists and warmongers perverted the concept of a "struggle for existence" into a rationale for genocide. However, we must admit a crucial difference between the two cases: the origin and later use of a biological feature, and the origin and later use of an idea. The first case involves no conscious intent and cannot be submitted to any moral judgment. But ideas are developed by human beings for overt purposes, and we have some ethical responsibility for the consequences of our actions. An inventor may be fully exonerated for true perversions of his intent (Hitler's use of Darwin), but unfair extensions consistent with the logic of original purposes do entail some moral demerit (most academic racists of the nineteenth century did not envision or intend the Holocaust, but some of their ideas did fuel the "final solution").

I want to examine the concept of "native plants" within this framework, for this notion encompasses a remarkable mixture of sound biology, invalid ideas, false extensions, ethical implications, and political usages both intended and unanticipated. Clearly, Nazi ideologues provided the most chilling uses.[1] In advocating native plants along the *Reichsautobahnen*, Nazi architects of the Reich's motor highways explicitly compared their proposed restriction to Aryan purification of the people. By this procedure, Reinhold Tüxen hoped "to cleanse the German landscape of unharmonious foreign substance."[2] In 1942 a team of German botanists made the analogy explicit in calling for the extirpation of *Impatiens*

Grapevines (Vitus *sp.*) *in northeastern Connecticut. This native is a commonplace of second-growth forest where its weight causes serious damage to its host trees.*

parviflora, a supposed interloper: "As with the fight against Bolshevism, our entire Occidental culture is at stake, so with the fight against this Mongolian invader, an essential element of this culture, namely, the beauty of our home forest, is at stake."[3]

At the other extreme of kindly romanticism, gentle arguments for native plants have stressed their natural "rightness" in maximally harmonious integration of organism and environment, a modern invocation of the old doctrine of *genius loci.* Consider a few examples from our generation:

> Man makes mistakes; nature doesn't. Plants growing in their natural habitat look fit and therefore beautiful. In any undeveloped area you can find a miraculously appropriate assortment of plants, each one contributing to the overall appearance of a unified natural landscape. The balance is preserved by the ecological conditions of the place, and the introduction of an alien plant could destroy this balance.[4]

> Evolution has produced a harmony that contrived gardens defy.[5]

Or this from President Clinton himself (though I doubt that he wrote the text personally), in a 1994 memorandum on "environmentally and economically beneficial practices on federal landscaped grounds": "The use of native plants not only protects our natural heritage and provides wildlife habitat, but also can reduce fertilizer, pesticide, and irrigation demands and their associated costs because native plants are suited to the local environment and climate."[6]

This general argument, of course, has a long pedigree, as well illustrated in Jens Jensen's remark in *Our Native Landscape,* published in his 1939 *Siftings:* "It is often remarked, 'native plants are coarse.' How humiliating to hear an American speak so of plants with which the Great Master has decorated his land! To me no plant is more refined than that which belongs. There is no comparison between native plants and those imported from foreign shores which are, and shall always remain so, novelties."[7]

Yet the ease of transition between this benevolent version and dangerous *Volkist* nationalism may be discerned, and quite dramatically, in another statement from the same Jens Jensen, but this time published in a German magazine in 1937:

> The gardens that I created myself shall . . . be in harmony with their landscape environment and the racial characteristics of its inhabitants. They shall express the spirit of America and therefore shall be free of foreign character as far as possible. The Latin and the Oriental crept and creeps more and more over our land, coming from the South, which is settled by Latin people, and also from other centers of mixed masses of immigrants. The Germanic character of our cities and settlements was overgrown. . . . Latin spirit has spoiled a lot and still spoils things every day.[8]

How slippery the slope between *genius loci* (and respect for all the other spirits in their proper places as well) and "my *locus* is best, while others must be uprooted, either as threats or as unredeemable inferiors." How easy the fallacious transition between a biological argument and a political campaign.

When biologically based claims have such a range of political usages (however dubious, and however unfairly drawn some may be), it becomes particularly incumbent upon us to examine the scientific validity of the underlying arguments, if only to acquire weapons to guard against usages that properly inspire our ethical opposition (for if the biological bases are wrong, then we hold a direct weapon; and if they are right, then at least we understand the argument properly, and can accurately drive the wedge that always separates factual claims from ethical beliefs).

Any argument for preferring native plants must rest upon some construction of evolutionary theory—a difficult proposition (as we shall see) because evolution is so widely misconstrued and, when properly understood, so difficult to utilize for the defense of intrinsic native superiority. This difficulty did not exist in pre-Darwinian creationist biology, because the old paradigm of "natural theology" held that God displays both his existence and his attributes of benevolence and omniscience in the optimal design of organic form and the maximal harmony of local ecosystems (see William Paley for the classic statement in one of the most influential books ever written).[9] Native must therefore


PETER DEL TREDICI

Cortaderia jubata *(sawgrass), weedy South American cousin of the garden-variety pampas grass, has invaded the hills of north-coastal California.*

be right and best because God made each creature for its proper place.

But evolutionary theory fractured this equation of existence with optimality by introducing the revolutionary idea that all anatomies and interactions arise as transient products of complex history, not as created optimalities. Evolutionary defenses of native plants rest upon two quite distinct aspects of the revolutionary paradigm that Darwin introduced. (I shall argue that neither provides an unambiguous rationale, and that many defenders of native plants have mixed up these two distinct arguments, therefore rendering their defense incoherent.)

The Functional Argument Based on Adaptation

Popular impression regards Darwin's principle of natural selection as an optimizing force, leading to the same end of local perfection that God had supplied directly in older views of natural theology. If natural selection works for the best forms and most balanced interactions that could possibly exist in any one spot, then native must be best for native has been honed to optimality in the refiner's fire of Darwinian competition. (In critiquing horticulturists for this misuse of natural selection, I am not singling out any group for an unusual or particularly naive misinterpretation. This misreading of natural selection is pervasive in our culture, and also records a primary fallacy of much professional thinking as well.[10])

In *Siftings,* Jens Jensen expressed this common viewpoint with particular force:

> There are trees that belong to low grounds and those that have adapted themselves to highlands. They always thrive best amid the conditions they have chosen for themselves through many years of selection and elimination. They tell us that they love to grow here, and only here will they speak in their fullest measure.[11]
>
> I have often marvelled at the friendliness of certain plants for each other, which, through thousands of years of selection and elimination, have lived in harmonious relation.[12]

The incoherencies of this superficially attractive notion may be noted in the forthcoming admission, in a work of our own generation, that natural does not always mean lovely. Natural selection does not preferentially lead to plants that humans happen to regard as attractive. Nor do natural systems always yield rich associations of numerous, well-balanced species. Plants that we label "weeds" will dominate in many circumstances, however transiently (where "transient" can mean more than a human lifetime on the natural time scales of botanical succession). Such weeds are often no less "native"—in the sense of evolving indigenously—than plants of much more restricted habitat and geography. Moreover, weeds often form virtual monocultures, choking out more diverse assemblages than human intervention could maintain. C. A. Smyser et al. admit all this, but do not seem to grasp the logical threat thus entailed against an equation of "natural" with "right" or "preferable": "You may have heard of homeowners who simply stopped mowing or weeding and now call their landscapes "natural." The truth is that these so-called no-work, natural gardens will be long dominated by exotic weed species, most of which are pests and look downright ugly. Eventually, in 50 to 100 years, native plants will establish themselves and begin to create an attractive environment."[13] But not all "weed" species can be called "exotic" in the sense of being artificially imported from other geographic areas. Weeds can be indigenous too, though their geographic ranges tend to be large, and their means of natural transport well developed.

The evolutionary fallacy in equating native with best adapted may be simply stated by specifying the essence of natural selection as a causal principle. As Darwin recognized so clearly, natural selection produces adaptation to changing local environments—and that is all. The Darwinian mechanism includes no concept of general progress or universal betterment. The "struggle for existence" can only yield local appropriateness. Moreover, and even more important for debates about superiority of native plants, natural selection is only a "better than" principle, not an optimizing device. That is, natural selection can only transcend the local standard and cannot operate toward universal "improvement"—for once a species prevails over others at a location, no pressure of natural selection need arise to promote further adaptation. (Competition within species will continue to eliminate truly defective individuals and may promote some refinement by selection of fortuitous variants with still more advantageous traits, but the great majority of successful species are highly stable in form and behavior over long periods of geological time—not because they are optimal, but because they are locally prevalent.)

For this reason, many native plants, evolved by natural selection as adaptive to their regions, fare poorly against introduced species that never experienced the local habitat. If natural selection produced optimality, this most common situation could never arise, for native forms would be "best" and would prevail in any competition against intruders. But most Australian marsupials succumb to placentals imported from other continents, despite tens of millions of years of isolation, during which the Australian natives should have attained irreplaceable incumbency, if natural selection worked for optimality rather than merely getting by. And *Homo sapiens*, after arising in Africa, seems able to prevail in any exotic bit of real estate, almost anywhere in the world!

Thus the first-order rationale for preferring native plants—that, as locally evolved, they are best adapted—cannot be sustained. I strongly suspect that a large majority of well-adapted natives could be supplanted by some exotic form that has never experienced the immediate habitat. In Darwinian terms, this exotic would be better adapted than the native—though we may well, on defensible aesthetic or even ethical grounds, prefer the natives (for nature's factuality can never enjoin our moral decisions).

We may, I think, grant only one limited point from evolutionary biology on the subject of adaptation in native plants. At least we do know that well-established natives are adequately adapted, and we can observe their empirical balances with other local species. We cannot know what an exotic species will do—and many, and tragic, are the stories of exotics imported for a

restricted and benevolent reason that then grew like kudzu to everyone's disgust and detriment. We also know that natives grow appropriately—though not necessarily optimally—in their environment, while exotics may not fit without massive human "reconstruction" of habitat, an intervention that many ecologically minded people deplore. I confess that nothing strikes me as so vulgar or inappropriate as a bright green lawn in front of a mansion in the Arizona desert, sucking up precious water that already must be imported from elsewhere. A preference for natives does foster humility and does counteract human arrogance (always a good thing to do)—for such preference does provide the only sure protection against our profound ignorance of consequences when we import exotics. But the standard argument—that natives should be preferred as best adapted—is simply false within Darwinian theory.

The Geographic Argument Based on Appropriate Place

This argument is harder to formulate, and less clearly linked to a Darwinian postulate, but somehow seems even more deeply embedded (as a fallacy) into the conventional argument for preferring native plants. This argument holds that plants occupy their natural geographic ranges for reasons of maximal appropriateness. Why, after all, would a plant live only in this-or-that region of 500 square kilometers unless this domain acted as its "natural" home—the place where it, uniquely, and no other species, fits best. Smyser et al., for example, write: "In any area there is always a type of vegetation that would exist without being planted or protected. This native vegetation consists of specific groups of plants that adapted to specific environmental conditions."[14] But the deepest principle of evolutionary biology—the construction of all current biological phenomena as outcomes of contingent history, rather than optimally manufactured situations—exposes this belief as nonsense.

Organisms do not necessarily, or even generally, inhabit the geographic area best suited to their attributes. Since organisms (and their areas of habitation) are products of a history laced with chaos, contingency, and genuine randomness, current patterns (although workable, or they would not exist) will rarely express anything close to an optimum, or even a "best possible on this earth now"—whereas the earlier notion of natural theology, with direct creation of best solutions, and no appreciable history thereafter (or ever), could have validated an idea of native as best. Consequently, although native plants must be adequate for their environments, evolutionary theory grants us no license for viewing them as the best-adapted inhabitants conceivable, or even as the best available among all species on the planet.

An enormous literature in evolutionary biology documents the various, and often peculiar, mechanisms whereby organisms achieve fortuitous transport as species spread to regions beyond their initial point of origin. Darwin himself took particular interest in this subject. During the 1850s, in the years just before publication of the *Origin of Species* in 1859, Darwin wrote several papers on the survival of seeds in salt water (how long would they float without sinking? would they still germinate after such a long bath?). He determined that many seeds could survive long enough to reach distant continents by floating across oceans—and that patterns of colonization therefore reflect historical accidents of available pathways, and not a set of optimal environments.

Darwin then studied a large range of "rarely efficient" means of transport beyond simple floating on the waves: for example, natural rafts of intertwined logs (often found floating in the ocean hundreds of miles from river mouths), mud caked on birds' feet, residence in the gut of birds with later passage in feces (Darwin and others studied, and often affirmed, the power of seeds to germinate after passage through an intestinal tract). In his usually thorough and obsessive way, Darwin assiduously collected information and found more than enough means of fortuitous transport. He wrote to a sailor who had been shipwrecked on Kerguelen Island to find out if he remembered any seeds or plants growing from driftwood on the beach. He asked an inhabitant of Hudson Bay if seeds might be carried on ice floes. He studied the contents of ducks' stomachs. He was delighted to receive in the mail a pair of partridges' feet

PETER DEL TREDICI

Eucalyptus globulus *is an important source of fuel and building material in the altiplano of South America, where in some cases it is the sole tree. This native of Tasmania and Victoria selfsows and has naturalized throughout the area.*

caked with mud; he rooted through bird droppings. He even followed a suggestion of his eight-year-old son that they float a dead and well-fed bird. Darwin wrote in a letter that "a pigeon has floated for 30 days in salt water with seeds in crop and they have grown splendidly." In the end, Darwin found more than enough mechanisms to move his viable seeds.

"Natives," in short, are the species that happened to find their way (or evolve *in situ*), not the best conceivable for a spot. As with the first argument about adaptation, the proof that current incumbency as "native" does not imply superiority against potential competitors exists in abundance among hundreds of imported interlopers that have displaced natives throughout the world: eucalyptus in California, kudzu in the American southeast, rabbits and other placental mammals in Australia, and humans just about everywhere.

"Natives" are only those organisms that first happened to gain and keep a footing. We rightly decry the elitist and parochial claims of American northeast WASPs to the title of native, but (however "politically incorrect" the point), the fashionable status of "Indians" (so-called by Columbus' error) as "Native Americans" makes just as little sense in biological terms. "Native Americans" arrived in a geological yesterday, some 20,000 years ago (perhaps a bit earlier), on the geographic fortuity of a pathway across the Bering Strait. They were no more intrinsically suited to New World real estate than any other people. They just happened to arrive first.

In this context, the only conceivable rationale for the moral or practical superiority of "natives" (read first-comers) must lie in a romanticized notion that old inhabitants learn to live in ecological harmony with surroundings, while later interlopers tend to be exploiters. But this notion, however popular among "new agers," must be dismissed as romantic drivel. People are people, whatever their technological status; some learn to live harmoniously for their own good, and others do not to their own detriment or destruction. Preindustrial

people have been just as rapacious (though not so quickly perhaps, for lack of tools) as the worst modern clear-cutters. The Maori people of New Zealand wiped out a rich fauna of some twenty moa species within a few hundred years. The "native" Polynesians of Easter Island wiped out everything edible or usable (and, in the end, had no logs to build boats or to raise their famous statues), and finally turned to self-destruction.

In summary of my entire argument from evolutionary theory, "native" plants cannot be deemed biologically best in any justifiable way (note that I am emphatically not speaking about ethical or aesthetic preference, for science cannot adjudicate these considerations). "Natives" are only the plants that happened to arrive first and be able to flourish (the evolutionary argument based on geography and history), while their capacity for flourishing only indicates a status as "better than" others available, not as optimal or globally "best suited" (the evolutionary argument based on adaptation and natural selection).

Speaking biologically, the only general defense that I can concoct for natives—and I regard this argument as no mean thing—lies in protection thus afforded against our overweening arrogance. At least we know what natives will do in an unchanged habitat, for they have generally been present for a long time and have therefore stabilized and adapted. We never know for sure what an imported interloper will do, and our consciously planted exotics have "escaped" to disastrous spread and extirpation of natives (the kudzu model) as often as they have supplied the intended horticultural or agricultural benefits.

As a final ethical point (and I raise this issue as a concerned human being, not as a scientist, for my profession can offer no direct moral insight), I do understand the appeal of the ethical argument that we should leave nature alone and preserve as much as we can of what existed and developed before our very recent geological appearance. Like all evolutionary biologists, I treasure nature's bounteous diversity of species (the thought of half a million described species of beetles—and many more yet undescribed—fills me with an awe that can only be called reverent). And I do understand that much of this variety lies in geographic diversity (different organisms evolved in similar habitats in many places on our planet, as a result of limits and accidents of access). I would certainly be horrified to watch the botanical equivalent of McDonalds' uniform architecture and cuisine wiping out every local diner in America. Cherishing native plants does allow us to defend and preserve a maximal amount of local variety.

But we must also acknowledge that strict "nativism" has an ethical downside inherent in the notion that "natural" must be right and best, for such an attitude easily slides to the Philistinism of denying any role to human intelligence and good taste, thence to the foolish romanticism of viewing all that humans might accomplish in nature as "bad" (and how then must we judge Frederick Law Olmsted's Central Park), and even (in an ugly perversion)—but realized in our time by Nazi invocation of nativist doctrine—to the claim that my "native" is best and yours only fit for extirpation.

The defense against all these misuses, from mild to virulent, lies in a profoundly humanistic notion as old as Plato, one that we often advance in sheepish apology but should rather honor and cherish: the idea that "art" must be defined as the caring, tasteful, and intelligent *modification* of nature for respectful human utility. If we can practice this art in partnership with nature, rather than by exploitation (and if we also set aside large areas for rigidly minimal disturbance, so that we never forget, and may continue to enjoy, what nature accomplished during nearly all of her history without us), then we may achieve optimal balance.

People of goodwill may differ on the best botanical way to capture the "spirit of democracy"—from one end of maximal "respect" for nature by using only her unadorned and locally indigenous ("native") products, to the other of maximal use of human intelligence and aesthetic feeling in sensitive and "respectful" mixing of natives and exotics, just as our human populations have so benefited from imported diversity. Jens Jensen extolled the first view: "When we are willing to give each plant a chance fully to develop its beauty, so as to give us all it possesses without any interference, then, and only then, shall we enjoy ideal land-

scapes made by man. Is not this the true spirit of democracy? Can a democrat cripple and misuse a plant for the sake of show and pretense?"[15]

But is all cultivation—hedgerows? topiary?—crippling and misuse? The loaded nature of ethical language lies exposed herein. Let us consider, in closing, another and opposite definition of democracy that certainly has the sanction of ancient usage. J. Wolschke-Bulmahn and G. Gröning cite a stirring and poignant argument made by Rudolf Borchardt, a Jew who later died trying to escape the Nazis, against the nativist doctrine as perverted by Nazi horticulturists: "If this kind of garden-owning barbarian became the rule, then neither a gillyflower nor a rosemary, neither a peach-tree nor a myrtle sapling nor a tea-rose would ever have crossed the Alps. Gardens connect people, times and latitudes. If these barbarians ruled, the great historic process of acclimatization would never have begun and today we would horticulturally still subsist on acorns. . . . The garden of humanity is a huge democracy."[16]

I cannot state a preference in this wide sweep of opinions, from pure hands-off romanticism to thorough overmanagement (though I trust that most of us would condemn both extremes). Absolute answers to such ethical and aesthetic questions do not exist in any case. But we will not achieve clarity on this issue if we advocate a knee-jerk equation of "native" with morally best, and fail to recognize the ethical power of a contrary view, supporting a sensitive cultivation of all plants, whatever their geographic origin, that can enhance nature and bring both delight and utility to humans. Is it more "democratic" only to respect organisms in their natural places (how, then, could any non-African human respect himself), or shall we persevere in the great experiment of harmonious and mutually reinforcing geographic proximity—as the prophet Isaiah sought in his wondrous vision of a place where the wolf might dwell with the lamb and such non-natives as the calf and the lion might feed together—where "they shall not hurt nor destroy in all my holy mountain."

Endnotes

1 J. Wolschke-Bulmahn and G. Gröning, "The Ideology of the Nature Garden: Nationalistic Trends in Garden Design in Germany During the Early Twentieth Century," *Journal of Garden History* (1992) 12(1): 73–80; G. Gröning and J. Wolschke-Bulmahn, "Some Notes on the Mania for Native Plants in Germany," *Landscape Journal* (1992) 11(2): 116–126; J. Wolschke-Bulmahn, "Political Landscapes and Technology: Nazi Germany and the Landscape Design of the *Reichsautobahnen* (Reich Motor Highways)," *Selected CELA Annual Conference Papers: Nature and Technology*, Iowa State University, 9–12 September 1995, vol. 7.

2 Quoted in Wolschke-Bulmahn, "Political Landscapes," from a 1939 article.

3 Quoted in Gröning and Wolschke-Bulmahn, "Native Plants."

4 C. A. Smyser et al., *Nature's Design: A Practical Guide to Natural Landscaping*, Emmaus, PA., 1982, xi.

5 K. Druse and M. Roach, *The Natural Habitat Garden*, New York: 1994, viii.

6 President William J. Clinton, *Memorandum for the Heads of Executive Departments and Agencies*, Office of the Press Secretary, 26 April 1994.

7 J. Jensen, *Siftings: The Major Portion of "The Clearing," and Collected Writings*, Chicago, 1956, 45.

8 Quoted in Wolschke-Bulmahn, "Political Landscapes," 13.

9 W. Paley, *Natural Theology*, London, 1802.

10 See S. J. Gould and R. C. Lewontin, "The Spandrels of San Marco and the Panglossian Paradigm: A Critique of the Adaptationist Programme," *Proceedings of the Royal Society of London B* (1979) 205: 581–198; see S. J. Gould, "Exaptation: A Crucial Tool for an Evolutionary Psychology," *Journal of Social Issues* (1991) 47(3): 43–65.

11 Jensen, *Siftings*, 47.

12 Ibid., 59.

13 Smyser et al., *Nature's Design*, vii.

14 Ibid., xi.

15 Jensen, *Siftings*, 46.

16 Wolschke-Bulmahn and Gröning, "The Ideology of the Nature Garden," 80.

Stephen J. Gould is professor of geology at Harvard University, curator of invertebrate paleontology at the Museum of Comparative Zoology, and Alexander Agassiz Professor of Zoology. Among his books and articles on the history of evolution and related topics are *Ever Since Darwin* (1977), *The Panda's Thumb* (1980), *The Flamingo's Smile* (1985), *Wonderful Life* (1989), and *Eight Little Piggies* (1993). This article evolved from a paper presented at the 1994 Studies in Landscape Architecture symposium at Dumbarton Oaks—"Nature and Ideology: Natural Garden Design in the Twentieth Century"—and published in 1997 under the same title, edited by Joachim Wolschke-Bulmahn.

E. D. Merrill, From Maine to Manila

Ida Hay

Twenty-two years of adventure in Southeast Asia preceded E. D. Merrill's career as director of several important botanical institutions, among them the Arnold Arboretum. His knowledge of the flora of Asia and the South Pacific was encyclopedic, and it was said he could name more species at sight than any other American taxonomist.

When twenty-six-year-old Elmer Drew Merrill left New York harbor for Manila on February 22, 1902, he had no idea that he would remain in the Philippines for the next twenty-two years, laying the foundation for a botanical inventory of the archipelago. After accepting a job offer as botanist with the Insular Bureau of Agriculture, he had had less than forty-eight hours to arrange his affairs, pack, and get to the boat. This rough-and-ready approach, spawned of a rigorous childhood in rural Maine, was to characterize Merrill's remarkable life: this would not be the last time he made a major career change at the drop of a hat.

From 1935 to 1946, Merrill was director of the Arnold Arboretum and Administrator of Harvard University's Botanical Collections, which included the Botanic Garden, the Gray Herbarium, the Bussey Institution, the Botanical Museum, the Harvard Forest, the Atkins Institution, and the Farlow Reference Library and Herbarium. When he arrived at Harvard, he had already had sixteen years' experience managing organizations with diverse functions, in addition to an extraordinary record of scholarship and publication in taxonomic botany.

Merrill was born in 1876 in East Auburn, Maine, a village of farmers and shoe factory workers, one of twins. He described his progenitors as simple, hardworking folk who, nevertheless, possessed the "pioneer spirit." His maternal grandfather was a forty-niner who journeyed to California by way of Panama, returning to his wife and children in Maine without having found any gold. Merrill's father had run away to sea at age fourteen and worked as a common sailor until he married; he continued to sign on for extended fishing trips to the Grand Banks during E. D.'s youth. It was the work and the pleasures of rural life that shaped Merrill's character, as he recalled years later:

> Swimming, boating, fishing, hunting, tramping in the woods—many things were more appealing to us than work, but when there was work to be done it always came first."[1]

Yet even at an early age he often found time to collect natural history specimens and to press plants.

Unlike their three older siblings, Elmer and his twin, Dana, continued their education beyond the elementary grades, attending high school in Auburn, three miles distant from their home. In one of his more telling comments on his background, Merrill wrote:

> Many times in winter we walked the entire distance to the city in a howling blizzard only to find "no sessions" because of the inclement weather. We came to have a rather scornful opinion of city people, not blaming the children, but rather the authorities. At times we made the trip on snowshoes. . . . This school experience doubtless had its effect in establishing one quality—that of persistence, a quality to which I believe I owe most of the success as I attained in after life.[2]

After graduating, both young men entered the Maine State College at Orono, which became the University of Maine in 1898, the year they

Merrill, right, and E. B. Copeland, left, with Joseph French and, standing, Henry Osgood, in the bachelor's mess in Manila, ca. 1905. From the time he arrived in the Philippines until he received an appointment as Associate Professor of Botany in the University of the Philippines in 1912, Merrill spent at least half his time working in the field. E. B. Copeland, who joined the botanical staff of the Bureau of Science in 1903, was one of Merrill's traveling companions. In 1909, accompanied by a group of American schoolteachers, the two climbed to the summit of Mount Pulog in northern Luzon, the third known ascent of the mountain by Westerners.

received their degrees. Although they enrolled as engineering students, they both transferred to the general science course after a surfeit of math classes during their first year. During his remaining undergraduate years, Elmer took as many biology courses as he could and studied the classification of flowering plants on his own since no formal training was offered. Like most New England botanists of his day, he tramped and botanized on New Hampshire's Mount Washington and likewise explored Mount Katahdin in northern Maine. He later gave his 2,000-specimen herbarium to the New England Botanical Club. He also traded a collection of his pressed plants dating from this period to Nathaniel Lord Britton for a copy of Britton and Brown's *Illustrated Flora of the Northern United States.* Though neither of them could have foreseen it, Merrill would one day succeed Britton as director of the New York Botanical Garden.

The outbreak of the Spanish-American War determined Dana Merrill's career choice. He enlisted in the Maine Volunteer Infantry, received his diploma *in absentia* that spring, and soon headed out to fight in the Philippines. He remained in the Army after the war and advanced through the ranks to brigadier general in 1935.

Elmer remained at Orono for a year after graduation. While he worked as an assistant in the Department of Natural Science, he took additional courses and continued to study systematic botany on his own. (In 1904, the University of Maine awarded him a master's degree for this work.) In 1899 he went to work in Wash-

ington at the U.S. Department of Agriculture (USDA) as an assistant agrostologist (a specialist in grasses, a family Merrill termed "particularly difficult"). He found the job rewarding and appreciated the opportunity to become more familiar with the literature of plant taxonomy, but he was still undecided about a career. With time on his hands evenings, he completed a year and a half of medical school. Then the offer of employment in the Philippines turned him permanently in the direction of plant science.

Among the many programs the U.S. government started in the Philippines after taking it over from the Spanish was an Insular Bureau of Agriculture, opened in 1901, the year before Merrill was persuaded by his boss at the USDA to accept the post of botanist there. He had expected to see his brother Dana when he arrived in Manila after the two-month voyage, but in the first of many ironies that would punctuate his life, he found that his twin had sailed for San Francisco two weeks earlier. It would be thirteen years before the two met again.

Merrill quickly applied his energies to the challenges of his new assignment. The previous two and a half years of work on the taxonomy of grasses had expanded his botanical purview from New England to Wyoming, Idaho, and Montana. Compared to that of the Western grasslands and Maine, however, the flora that he now confronted was exuberant and vastly complex. Undaunted, he immediately envisioned a complete survey of the Philippine archipelago, 7,000 tropical islands with extensive, mountainous, old-growth forest ringed by lowlands that had been cultivated for centuries.

Resources for studying this fascinating flora were almost nonexistent in Manila; any botanical specimens and literature that had been assembled during the long years of Spanish rule had either burned in the 1898 war or disappeared during the disruptive period of American takeover. Never one to hesitate, Merrill immediately started collecting weeds behind the vacant house that served as headquarters for the Bureau of Agriculture. And within a month he had left on his first collecting expedition, a six-week trek through the mountains of Luzon to Aparri on the north coast. For the next eleven years he would spend nearly half his time in the field.

Government officials in Manila quickly recognized Merrill's abilities and gave him an additional appointment to the Bureau of Forestry, thereby consolidating botanical research. In 1903 all botanical work was transferred to the Bureau of Government Laboratories, which in 1906 became the Bureau of Science.

LIBRARY OF THE ARNOLD ARBORETUM

Bureau of Science buildings in Manila, 1916. Although Merrill's work in the Philippines commenced in a vacant dwelling rented as headquarters for the Bureau of Agriculture in 1902, within three years a new facility was constructed to house the Bureau of Science. Merrill was director of the Bureau from 1919 to 1923. The destruction of these buildings, along with most of their contents including the herbarium and botany library, during World War II was a tragic episode in Merrill's career, even though he was director of the Arnold Arboretum by that time.

From the outset Merrill spent much time and energy building the reference library that was needed to identify the rich flora he found during his explorations. In 1902 he made a visit to the 85-year-old botanical garden in Buitenzorg, Java (Bogor). He found the library and herbarium there very helpful; in addition to identifying the Philippine plants he had brought along, he was able to familiarize himself with the botanical literature of the Malay Archipelago, the great chain of islands stretching from southern Asia to northern Australia. Undoubtedly this visit inspired his efforts to amass similar resources in Manila: by the time he left the Philippines in 1923, the herbarium had grown from almost nothing to over 250,000 specimens, complemented by a library he characterized as one of the most complete in all of Asia.

Adventures in the Field

Merrill's travels in search of plants took him the length and breadth of the archipelago and included remote areas where few, if any Filipinos, let alone Westerners, had set foot. One of these was the summit of Mount Halcon, which he and a party of forestry and military personnel reached in November 1906 after twenty days of arduous, wet climbing. There existed no report of Westerners having previously attained the summit of this mountain; and apparently local Mangyan tribespeople had never ascended either, for no signs of trails were seen anywhere near the peak and Merrill was sure that no human could get there without cutting a trail, so dense was the mossy forest and so steep the terrain.

Halcon, at 8,500 feet the third highest mountain in the Philippines, is located on northern Mindoro, one of the most humid areas in the entire country. Halcon and its subsidiary ranges capture an enormous amount of precipitation nearly year-round, and the mountain is continually shrouded in fog and clouds. During the ascent Merrill encountered the entire gamut of rainforest vegetation that he later came to know so well. Starting from Calpan to the north, the party soon left behind the coastal lowland with its mangrove swamps, cultivated crops, and abundant tropical weeds. They followed river courses and occasional Mangyan trails through dense vegetation dominated by huge trees with canopies so high and thick that only twilight reached the forest floor. For the most part this was primary forest with a several-storied, species-rich mix of trees that included many Dipterocarpaceae. They also encountered many areas of secondary forest, the abandoned clearings of the Mangyan people who regularly cleared a few acres of the old-growth forest, burned it over, then planted upland rice, corn, and other crops for a year or two before moving on to a new area. Once cultivation stopped, these clearings were rapidly re-vegetated by a mix of indigenous and introduced plants quite different from those of the original rainforest.

Travel was extremely difficult. The rivers the party followed often led them into steep-sided ravines, forcing them to ford the swift water frequently. Then, after finally reaching the ridges at the top of the canyon walls, they had to hack their way slowly through more forest using bolos, the Filipino equivalent of machetes. Sometimes the only way to proceed was to chop their way up 80-degree slopes.

Once they attained 4,000 feet, the vegetation began to change markedly to that known as the mossy forest—a diverse mix of smaller trees including oak, maple, and several Malaysian genera with many-branched, scraggly habits, as well as *Rhododendron*, *Vaccinium*, *Rubus*, and other shrubby genera found in more temperate regions. Moisture-loving ferns, mosses, and epiphytes grew even more profusely here at higher elevations than they had in the lower forests:

> Epiphytic ferns and orchids . . . become more plentiful and there is a greater diversity in species; mosses are much thicker and more luxuriant, enwrapping even the branches and branchlets of trees and forming a deep, soft, soil cover, frequently a foot in thickness.[3]

The going was not easier in the mossy forest, even though the woody vegetation became more and more stunted the higher they climbed. Thickets of gnarled trees and branching shrubs, covered with epiphytes and intertwined with vines, allowed no forward progress without first clearing a trail step by step. The temperature had dropped considerably, averaging 60 degrees Fahrenheit in the daytime, and a rainy period that lasted thirteen days set in.

ARCHIVES OF THE FAIRCHILD TROPICAL GARDEN

Veitchia merrillii *(formerly* Adonidia merrillii*). The Christmas palm or Manila palm is admired for its pendulous clusters of crimson fruit, which contrast attractively with its whitish fruit stalks and sheaths. It was known only from cultivation in the vicinity of Manila when named for Merrill by Italian palm specialist Odoardo Beccari (1843–1920). Later the Manila palm's native habitat was determined to be restricted to Palawan and the Calamianes Islands on the basis of specimens collected by Merrill and A. D. E. Elmer, one of his colleagues at the Philippine Bureau of Science.*

Surprisingly, when they reached 7,800 feet, the montane brush gave way to vegetation Merrill described as open heath, a collection of tufted grasses broken only occasionally by stunted trees and shrubs. They quickly traversed this area only to find that the final 500 feet of elevation was covered with thickets more dense than any they had previously encountered:

> At times as we came to the crest line, the cold wind would add to our discomfort. . . . Pitcher plants *(Nepenthes)* became very abundant, clambering everywhere in the thickets, so that in cutting our way through the underbrush, at frequent intervals our bolo slashes would upset the equilibrium of from one to a half a dozen pitchers, each holding one-half quart or more of water, which would be precipitated upon us. These irregular douches were far more disagreeable than the constant shower bath from the falling rain.[4]

In storms worse than ever, Merrill and another scientist reached the summit, where clouds obscured the view. They quickly took barometric readings and left a record of their visit sealed in a bottle tied to a tree, since there were no boulders to use for a cairn.

The return trip to the coast took nearly as long as the ascent. They were delayed by more storms, and two members of the party became lost for a while. When the porters were sent back to retrieve supplies left at lower elevations and got cut off by rain-swollen rivers, the party had to forage in the rainforest for a Thanksgiving "dinner" of broiled wood rats and boiled fern tips. Merrill commented that "a man can come nearer to starving to death in a primary tropical forest than in almost any other part of the world," since there is little game, and edible fruit is either too high in the canopy or too widely spaced for efficient harvesting. It was some consolation to Merrill that a new species was later described from the rat skins and skulls left over from the holiday dinner.

Although this was probably the most strenuous of his field trips, Merrill accepted many more challenges in his search for the Philippine flora. On some occasions he walked 36 miles in a single day. There were precarious landings in the surf on remote coasts, and the unnerving experience of collecting plants among the hastily made graves of tribesmen who had resisted American troops. And at times he risked his life by staying overnight in remote villages of the Mountain Province, where headhunters were reputed to live.

In order to determine the relationships between the flora of the Philippines and those of surrounding areas, as well as for help in identifying certain species, Merrill and his associates at the Bureau of Science also made collecting trips to Guam, Borneo, Amboina, Indochina, and China. He acquired additional specimens for the herbarium collection in Manila by exchanging material from the Philippines for Indo-Malaysian, Australian, and Polynesian plants.

Publications

Of course, the fieldwork was only the beginning for Merrill. His observations in the field and subsequent scrutiny of pressed specimens, along with intense study of botanical literature,

LIBRARY OF THE ARNOLD ARBORETUM

Elmer Drew Merrill photographed in Manila, 1914.

The Arnold Arboretum

S P R I N G · N E W S · 1 9 9 8

Katherine H. Putnam Research Fellowships Endowed

Janet Stearns

George Putnam, chairman, Putnam Funds and the Putnam Investment Company (second from left), and his wife Nancy Putnam, display a photo taken in turn-of-the-century China by E. H. Wilson; it was presented to them by the Arboretum at a reception held in their honor. Standing with the Putnams are James McCarthy (left), director, MCZ, and Robert E. Cook, director, Arboretum.

Fifty friends of George and Nancy Putnam gathered in Cambridge on Friday, May 15, to show their appreciation for two generous endowments established by the Putnams. Two of Harvard's oldest biological institutions, the Arnold Arboretum and the Museum of Comparative Zoology, will benefit from endowments of $1 million each to support research and scholarship.

The endowment at the Arnold Arboretum will support the Katharine H. Putnam Research Fellowships, established in memory of Mr. Putnam's mother, an accomplished horticulturist and long-time supporter of the Arboretum. The funds will provide fellowship stipends and related research and project expenses for work in horticulture and botany using the Arboretum's living collections of trees and shrubs.

Putnam Fellowships will fund graduate students, postgraduate scholars, and mid-career professionals who wish to experience the richness of the Arboretum's resources and engage in research work that generates new knowledge and practical applications for horticulture, landscape architecture, and plant conservation. Fellowship awards will be particularly appropriate for young research scientists contemplating a career in public horticulture and education.

"George Putnam has been a friend of the Arboretum for many years," says director Bob Cook. "With the establishment of the Putnam Fellowship endowment, we can continue to offer the most promising scientists an opportunity to work with our collections and to gain the kind of practical experience that is essential for leadership nationally. We deeply appreciate the commitment of George and Nancy Putnam to this critical research and the educational mission of the Arnold Arboretum."

What a Difference a Year Makes

Peter Del Tredici, Director of Living Collections

On Monday, March 31, of last year, I was sitting in Patrick Willoughby's office in the basement of the Hunnewell building as he told me that he had decided to take the job as head of grounds maintenance at Wellesley College, and that his last day as Superintendent would be May 1. As I listened to Patrick talk about his future, I was looking out the window at the occasional snowflakes that had just started to fall. "It won't stick," I said, "none of it has this winter." Within 24 hours I

was eating those words. Two feet of sticky wet snow had been dumped on the city of Boston, stopping traffic, downing power lines, and smashing trees. As most people reading this will remember, the Arnold Arboretum was particularly hard hit: over 1,800 trees were damaged, of which 200 have been removed.

But now it is one year later and I am pleased to report that a new superintendent, Julie Coop, is well established in Patrick's old office, and most of the storm damage has been cleaned up. Of particular interest is the fact that the high temperature on the day of the storm was 42 degrees while on the same date one year later, the high was 92! What a difference a year makes.

Spring planting, which was virtually nonexistent last year, has gone very smoothly this year. Over 150 new trees were set out during April alone. Unlike last year, this spring there was no snow to speak of and the weather was moist and cool. This not only allowed the grounds crew to start digging early, but also to dig and plant throughout the entire month.

On behalf of all of us at the Arboretum, I want to take advantage of this dubious anniversary to thank all of our loyal friends and supporters who generously donated labor and money to our storm damage cleanup effort. The donations not only helped with the clean-up, but they also lifted the spirits of the entire Living Collections staff. It's great to know that people care deeply about the future of the Arnold Arboretum. Thank you very much.

CHALLENGE GIFT FOR CHILDREN'S SCIENCE EDUCATION

The Arboretum has received a challenge gift of $100,000 from an anonymous donor. The gift has been directed to Children's Science Education and is intended to encourage others to help endow the Arboretum's Field Studies Experiences (FSE) program.

The FSE program brings children directly from Boston-area classrooms to the Arboretum's landscape. Students work in small groups with a guide while exploring and discussing specific science questions related to one of four different themes: Flowers Change; Plants in Autumn; Native Trees, Native Peoples; and Around the World in Trees. Each year the program serves 3,000 schoolchildren in grades three through five.

The Arboretum's goal in the Harvard University Campaign is to establish an endowment of $2,250,000 that will secure funding for children's science education. Of the total goal, $750,000 will create an endowment for the FSE program. To date, $439,000 has been raised, representing 59% of the goal. "The creation of an endowment for children's science education is critical to our education mission," says director Bob Cook. "It addresses a pressing need for excellence in science education and demonstrates our commitment to children, our most important resource for the future."

If you are interested in making a gift to help the Arboretum qualify for this challenge gift, or would like a copy of our publication "The Arnold Arboretum—An Outdoor Classroom," please contact Lisa M. Hastings, Director of Development, at 617/524-1718 x 145.

Harvard Announces Women's Matching Fund

At a recent forum on women and philanthropy, Harvard announced an initiative aimed at encouraging more women to participate in philanthropy. The Women's Matching Fund will match any gift between $25,000 and $250,000 made by women to any part of the University.

The Women's Matching Fund was created by National Campaign Chair Rita E. Hauser as a way for women to maximize the impact of their gifts to Harvard. Ms. Hauser established the fund with her own gift of $5 million and encouraged other women to bring the fund balance to $15 million. Gifts made by women will be matched on a dollar-for-dollar basis until the fund is depleted.

This new fund offers women who are considering a campaign gift to the Arboretum a unique opportunity to double their gifts. Gifts qualifying for the match can be directed to any of the Arboretum's campaign priorities: Living Collections (including landscape maintenance projects), Children's Science Education, International Biodiversity Conservation, and the new Shrub and Vine Garden.

For more information about the Women's Matching Fund, contact Lisa M. Hastings at 617/514-1718 x 145, or Peg Hedstrom at x 113.

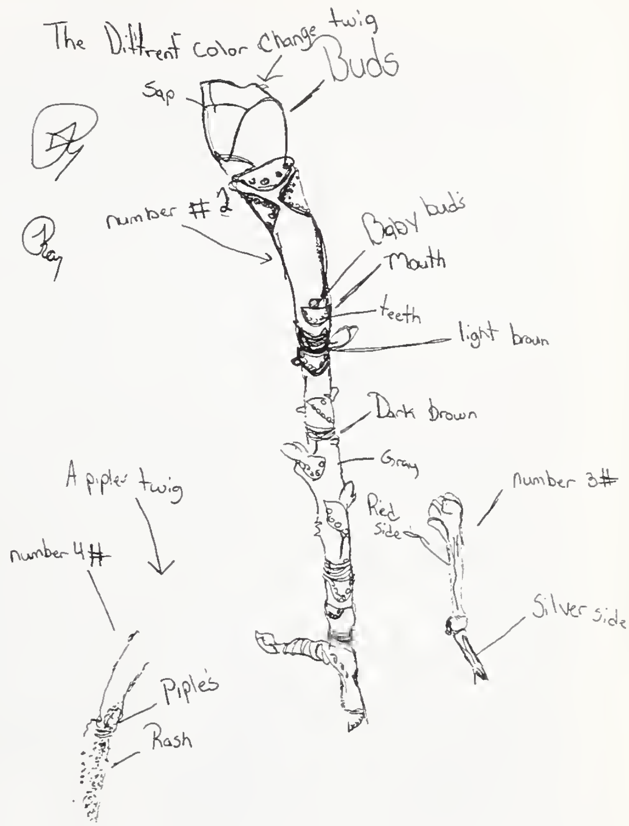
Community Science Connection Goes National

Candace Julyan, Director of Education

In 1995 the Arnold Arboretum received a four-year grant from the National Science Foundation to develop a program to strengthen elementary science teaching and learning and to illustrate ways that science institutions can work throughout the year with local classrooms. The result of this effort is the Community Science Connection (CSC), a seasonal study of trees that spans the entire school year.

Participating teachers begin their study of trees in the spring and summer, learning how to look closely for patterns and changes and to make sense of what they see. In the fall, students begin their work by identifying individual trees and recording the dates when color change begins and ends and when the leaves drop. In the winter, students learn to "read" the information found on a twig and to use that knowledge to determine the best growing year for their schoolyard trees. In the spring, the study question turns to "What comes out of a bud?" While the main focus is on working directly with schoolyard trees, technology provides a connection among the participating classrooms and the Arboretum staff. A project web page enables participants to share data and ideas and provides virtual activities that encourage and support the outdoor investigations.

The goals of CSC are twofold: to work directly with local teachers on meaningful ways to study science through an investigation of trees and to develop a model that can be replicated by other institutions to further their work with local teachers. The first year of the project focused on the first goal. To date we have worked with over fifty teachers in the Boston, Newton, and Brookline schools. In the final year of the project we will continue to work with local teachers and begin work with other science institutions. Descanso Gardens, in collaboration with the science coordinator of the Los Angeles public schools, will replicate our tree investigations with California students. (The director of Descanso, Richard Schulhof, worked on the CSC project during its first year in his former role as the Arboretum's director of public programs.) Los Angeles students and their teachers will be corresponding with Massachusetts colleagues through the website, comparing findings from coast to coast. This work will give us an opportunity to determine the viability of our model for other institutions.



Another interesting development in this project emerged during the past year. The Massachusetts Audubon Society (MAS) was intrigued by our seasonal investigations and used it as a model to create a year-long study of vernal pools. During the 1998–1999 school year, groups of teachers from eastern, central, and western Massachusetts will begin a coordinated study of vernal pools that will continue through fall, winter, and spring based on a curriculum outline developed by MAS. These investigations will be supported by the same technology component as the tree studies, with a data exchange, opportunities for conversations, and virtual activities that go along with the actual investigations. All of the technology portion of the MAS project will originate from the Arboretum and the virtual activities will be a joint development venture between staff from MAS and the Arboretum.

While the conversations of the participating classes will remain private, all of the activities for these investigations will be available to interested individuals through the Arboretum's web page (www.arboretum.harvard.edu). We welcome your comments.

On the Grounds

Tom Akin has joined the Arboretum staff as Assistant Superintendent of Grounds. A candidate for the master's degree in plant and soil sciences at the University of Massachusetts, Amherst, he has worked with the University's Extension Service both as a research assistant and extension educator. He comes to us from Weston Nurseries where he was IPM (Integrated Pest Management) Coordinator. Tom's resumé also includes work with the Peace Corps in the Central Africa Republic, first as an English teacher, then as keeper of African killer bees. No doubt he will bring all these experiences to bear at the Arboretum, where his duties will include the coordination of the summer horticultural intern program and its associated training program.

Karen Madsen

So Long, Fare Well

Karen Madsen

Jim Gorman, Arboretum tour leader and volunteer coordinator nonpareil, is leaving us for southeastern Pennsylvania and the Longwood Gardens Graduate Program in public horticultural administration. An official staff member at the Arboretum since 1992 and an unofficial staff member even longer, Jim Gorman and the Arnold Arboretum have been synonymous for many in Boston. Wherever his future takes him, we know he will continue to be the best emissary we could hope for. Needless to say, we will miss him, and we wish him all the best.

Annual Fall Plant Sale

Sunday, September 20, 1998
Case Estates, Weston
9:00 am to 1:00 pm

The date has been set for this year's Annual Fall Plant Sale, and we encourage members of the Friends of the Arnold Arboretum and the general public alike to mark their calendars. As usual, the event will feature a wide array of unusual trees, shrubs, herbaceous perennials, and more.

Member benefits at the Plant Sale include "members only" hours from 9:00 to 10:00 am, a free plant of your choice, and a 10% discount on all plant purchases in the Barn. Members at the Sustaining Level ($100) and above gain entrance to the Plant Sale Preview at 8:30 and receive additional free plants. Call the Membership Office at 617/524-1718 x 165 to join or to upgrade your membership and increase your Fall Plant Sale benefits!

Live and Silent Auctions
Straight Sales
Society Row
Education Sessions in the Teaching Garden
Refreshments

Catalogs will be mailed to members in August, and your free plant vouchers will arrive in early September. To volunteer to help out at the Plant Sale, call Kara Stepanian at 617/524-1718 x 129.

A circle of distinguished friends photographed in the 1940s. Seated from left, Merrill, plant explorer and collector David Fairchild, naturalist and herpetologist Thomas Barbour, and standing, citrus hybridizer Walter T. Swingle and paleontologist Theodore White, in Barbour's Florida garden.

became the material for a prodigious output of publications. He worked assiduously not only on problems of identification and classification but on nomenclature and bibliography as well. In the course of this work, for example, he published several papers updating Manuel Blanco's 1837 *Flora de Filipinas.* His long-term goal was to produce a complete descriptive flora for the Philippines, but first many new species had to be described and published, and their relationships with other plants explained.

"New or Noteworthy Philippine Plants," a series of some seventeen papers, was published intermittently from 1904 to 1922. Merrill also published about twenty revisions of genera or families as they occur in the Philippines. Altogether, between 1904 and 1929, he authored one hundred strictly taxonomic papers on the Philippine flora. Most were published in the Botanical Section of the *Philippine Journal of Science,* which Merrill edited from 1907 to 1918.

The publication in 1912 of the 500-page *A Flora of Manila* was a major step toward his longer-term goal. Since the 1,007 species it covered—a small percentage of the total known for the entire country—were those that inhabited low altitudes and could be found in most towns, this work provided a useful guide for the Philippine people.

But the tasks Merrill assigned himself were not limited to the Philippine flora. In the course of studying the origins of Philippine plants and their relationships to the vegetation of neighboring regions, he wrote exhaustive commentaries on the work of earlier botanists, including the pre-Linnean work of Rumphius on the flora of Amboina in the Moluccas, and the *Flora Cochinchinensis* (1790) of Portuguese missionary Juan Louriero; assembled a great deal of information on the literature of Malaysian botany, and became an expert on the local names for plants of Southeast Asia as well as the biogeography of the region. He also published papers on the plants of Borneo, Guam, Sumatra, Hainan, and Papua, often based on the many specimens that he received from those areas.

Having begun his botanical career at the USDA and gone to the Far East under the auspices of the Department's divisions of agriculture and forestry, Merrill was ever aware of the practical aspects of plant science and of the human influence on the flora. His observations on introduced weeds, cultivated plants, and local plant names initiated a lifelong interest in the origins of agriculture and the migration of plants in pre-Columbian times. "The American Element in the Philippine Flora" (1904), "Medical Survey of the Town of Taytay: The Principal Foods Utilized by the Natives" (1909), and "Notes on the Flora of Manila with Special Reference to the Introduced Element" (1912) are some of his earliest papers in economic botany.

In all his many publications on the flora, Merrill rarely failed to comment on the destruction of forests and other changes in ecosystems caused by human activities:

> The practical extermination of the original vegetation of those regions best adapted to agricultural pursuits is a subject that deserves more consideration than it has received. Unquestionably, many species of plants have been exterminated in various parts of the Malayan region within the past century as the population has increased. The areas being devoted to agriculture are being rapidly enlarged . . . and the consequent destruction of primeval forests over large areas is a strong argument in favor of vigorous and intensive botanical exploration of Malaya.[5]
>
> The enormous trees and shade plants characteristic of the primary forest cannot persist under the conditions demanded by modern agriculture, and they cannot exist in second growth forest, grasslands, and bamboo thickets that rapidly encroach on cleared areas that are abandoned. . . . We are witnessing in our own generation the rapid extermination of some of the noblest types of tropical vegetation . . . [6]

When Merrill wrote these words, the population of the Philippine Islands was less than that of greater London; today the population is ten million greater than that of all the British Isles.

Becoming an Administrator

Merrill would have loved to spend all his time working in systematic botany, but in 1912 a series of additional appointments began to claim much of it. In that year he was appointed Associate Professor of Botany at the University of the Philippines; subsequently, his teaching duties would occupy from 18 to 36 hours per week. Then, in 1919, he was appointed director of the Bureau of Science after a six-month stint as acting director. In this capacity his responsibilities included medicine, public health, chemistry, weights and measures, materials testing, geology, mining, fisheries, zoology, and anthropology, in addition to botany. Although he accepted the position "with diffidence and reluctance," he found in himself a talent for handling problems in fields widely divergent from his own, and his executive ability quickly won him respect. It is perhaps not surprising that the botanist whose identical twin became a brigadier general turned out to have a knack for administration.

But his new role cut even more severely into the time available for preparing the major work he had contemplated:

> My appointment of Director of the Bureau of Science in 1919 clearly indicated to me that I could scarcely hope to consummate my plan of preparing and publishing a general descriptive flora of the Philippines, as I soon realized that most of my botanical work would of necessity have to be done outside of office hours. I accordingly compromised with myself and . . . commenced the actual preparation of my 'Enumeration of Philippine Flowering Plants.'[7]

The four-volume *Enumeration* was issued between 1922 and 1926. In it Merrill attempted to:

> account for all binomials accredited to the Philippine flora, adjust the synonymy, cite all important literature references, illustrative [specimens] when desirable, determine the Philippine and extra-Philippine distribution of each species and record native names.[8]

While it was not the complete, descriptive work that he had hoped to produce, it was a valuable summation of all that he and his colleagues had accomplished. The *Enumeration* allowed Merrill to outline his conclusions on the relationship of the Philippines' climate, geologic history, and plant life to those of adjacent regions. Also included were discussions of the original settlement of the islands; their peoples and languages; and the history of botanical study in the Philippines. Unexpectedly, the

Enumeration served as a kind of closure to Merrill's years in the Philippines, for as it turned out, he left Manila in the fall of 1923 never to return.

The Scientist-Administrator Moves On

Merrill's departure was almost as abrupt as his arrival: he was given only a week to decide whether to accept a position as dean of the College of Agriculture at the University of California. Had there been no family dependent on him, he would undoubtedly have remained in the Philippines. But in 1907 he had married Mary Augusta Sperry of Illinois. After the wedding in Manila, the couple spent a year traveling to China and Japan, followed by a several-month stay in Washington, D.C., and visits to London, Leiden, Berlin, and Florence, where Merrill studied in herbaria. Once settled back in Manila, Mary gave birth to three children over the next seven years. When the third child died in infancy, the Merrills concluded that "Manila was not the proper place in which to bring up a family." In 1915, at the end of another visit to Washington, Mrs. Merrill stayed on with the two children. Elmer returned to Manila and did not see his fourth child, born in 1916, until she was nearly five years old.

> It was not easy to leave the scene of so many years of work, the city in which I made such reputation I bear as a botanist.[9]

As he left Manila in 1923 Merrill took some comfort in the good will of his American and Filipino colleagues in the Bureau of Science and in the resources that he left behind for the ongoing work of inventorying the Philippine flora: a fine library and herbarium, and an exhaustive body of research. Through the field collecting of Merrill and his coworkers, the list of known Philippine species had been extended from 2,500 plants of all types in 1900 to 8,120 species of flowering plants, 1,000 species of ferns, and 3,000 species of cryptogams by 1926, when the final volume of the *Enumeration* was published. Perhaps the greatest of all the ironies in Merrill's life would come during World War II, when the collections of the Bureau of Science were destroyed by Japanese bombs.

By that time Merrill was at the Arnold Arboretum and in a position to help rebuild the collections. As soon as the fighting ended, he rallied curators at Harvard and other major herbaria to send duplicate specimens and library materials to the Philippines. Work on the complete flora of the Islands has been carried forward in recent years by Philippine and American botanists at the Philippine National Herbarium, the Bishop Museum, and the Botanical Research Institute of Texas, using Merrill's meticulous scholarship as a starting point. Tragically, many of the plants to be included may no longer exist by the time the flora is published, since rainforest is being destroyed in the Philippines at a rate second only to Madagascar's. Of the extensive primary forests that once covered the mountainous archipelago, current estimates are that less than three percent remain intact.

Endnotes

1 E. D. Merrill (hereafter EDM.), "Autobiographical: Early years, the Philippines, California," *Asa Gray Bulletin* n.s. (1953) 2(4): 338.

2 Ibid.

3 EDM, "The Ascent of Mount Halcon, Mindoro," *Philippine Journal of Science*, section A (1907) 2(3): 200.

4 Ibid., 195.

5 EDM, "An interpretation of Rumphius's Herbarium Amboinense," *Bureau of Science Publication*, Manila (1917) 9: 25–26.

6 EDM, "A bibliographic enumeration of Bornean plants," *Journal of the Straits Branch of the Royal Asiatic Society* (1921) Special number: 27–28.

7 EDM, "Autobiographical," 357.

8 Ibid.

9 Ibid, 359.

For Further Reading

Merrill, E. D. 1945. *Plant Life of the Pacific World*. NY: Macmillan.

———. 1955. Real values. *Asa Gray Bulletin* n.s. 3(1): 27–32.

Editors. 1946. Merrilleana, a selection from the general writings of Elmer Drew Merrill. *Chronica Botanica* 10: 127–394.

Ida Hay, a member of the Arnold Arboretum staff for over twenty years, is the author of *Science in the Pleasure Ground*, a history of the Arnold Arboretum published in 1995 by Northeastern University Press. She now lives in Northampton, Massachusetts.

Light in a Bottle: Plant-Collecting in the Philippines

Rob Nicholson

There has been no better time to be a field botanist. It is from the world of plants that cures are again being sought, and compounds isolated from plants are being tested for their anti-viral, anti-cancer, and anti-fungal activity. A small corps of botanists are journeying to the field, gathering samples of bark, leaf, and root, and trundling them back to the biochemistry labs of the world.

The status of botanical compounds has risen in recent years with the success of the taxane group of compounds in fighting cancer. However, funding for research on medicinal plants is notorious for its boom-and-bust cycles, and if the current well-funded efforts bring no major leads, a new downcycle in support may be triggered. At the same time, there is an urgent sense among botanists returning from the field that the work must be done now or never. The relentless spread of human population means that forests continue to be turned into fields and pastures and that individual plant species are harvested into extinction by the multitudes of people who value their timber, flowers, or aphrodisiac bark.

Botanical field collecting for medicinal leads usually proceeds in two phases. Initially a broad assortment of plants is collected from a certain region or from a specified set of plant families. Extracts are made and laboratory-tested for effectiveness against a variety of diseases. If a particular species shows promise—the San Pedro cactus, let us say—the second phase begins with a search for different populations of the same species or for other species within the genus—perhaps the San Roberto cactus—in hopes of achieving a still higher level of effectiveness. Essentially, then, it is find a needle in the haystack, then find a better needle.

Over the last twelve years most efforts have focused on cancer and the HIV virus, and scores of botanical compounds have been tested on cell cultures of these diseases. The work is coordinated by the Developmental Therapeutics Program of the National Cancer Institute (NCI) under the directorship of Dr. Gordon Cragg. Since 1985 over 30,000 plant extracts have been tested for in-vitro effectiveness against sixty types of cancerous tumors, and over 52,000 have been tested against HIV since 1987. Once an effective compound has been isolated and patented, the NCI licenses it to a pharmaceutical firm for further development.

Homolanthus as a Potential Anti-HIV Therapy

Dr. Cragg reported in 1994 that "four novel plant-derived agents with in-vitro anti-HIV activity have been isolated and selected for preclinical development." Among these are extracts from a *Conospermum* species of Australia, *Ancistrocladus korupensis* of Cameroon, and *Calophyllum* of southeast Asia, which was collected and identified by researchers at the Arnold Arboretum and is now in Phase II human clinical trials. A fourth genus of interest to NCI is *Homalanthus.*

There are about 35 species of *Homalanthus*, ranging throughout Indomalaysia and Polynesia. Because none of these is very appealing aesthetically, little had been written about them since 1914, when Elmer Merrill (later director of the Arnold Arboretum) described a number of *Homalanthus* species from the Philippines. Then in the late 1980s, after a decade of work-

MELVIN SHEMLUCK

In lush and humid lowland rainforest, the plant-collecting party stops to catch their breath before a final push up Mt. Apo, the highest peak in the Philippines.

MELVIN SHEMLUCK

Amid razor-sharp sawgrass and burnt trunks, expedition members were successful in locating a handful of young Taxus *plants to be tested for anti-cancer activity.*

ing with native healers in Samoa, botanist Paul Cox of Brigham Young University returned to the United States with a number of samples for laboratory analysis, together with documentation of their local medicinal uses. One of Cox's specimens was *Homalanthus nutans.* As members of the euphorbia family, *Homalanthus* are related to such plants as crotons, poinsettia, cassava, and castor beans. Some members of the family contain milky latexes that cause gastrointestinal poisoning, dermititis, or tumors, but a number of them have been used medicinally worldwide to relieve toothaches and oral infections, or as emetics and laxatives.

Plants of the genus *Homalanthus* are small trees, weedy colonizers that thrive along the edges of roads and fields or in newly opened spaces in the forest canopy. Samoans know them as *mamala* and use their bark, leaves, stems, and roots to treat a variety of ailments, one being yellow fever. In Western laboratories a compound extracted from the wood, prostratin, was found to strongly inhibit the killing of human host cells in-vitro by the HIV virus. This first flash of promise set off a cycle of activity. Botanists began collecting and studying the plant, and chemists initiated studies to decipher its mode of activity, thus giving it status as a candidate for clinical trials.

Botanists Take To the Field

At the same time that studies were revealing the medicinal potential of *Homalanthus,* my research partner, Dr. Melvin Shemluck, and I secured a grant from the United States Department of Agriculture to continue our previous research on wild populations of yew, this time collecting live material in the Philippines. *Taxus,* the yew genus, had been the subject of intense research for over a decade thanks to the

MELVIN SHEMLUCK

The cabbage fields of Mt. Pulog represent a classic dilemma of developing countries: increased food production vs. biodiversity conservation.

discovery of the compound taxol, an anti-cancer agent found in its needles and bark. We were focusing on disjunct yew populations in order to learn which species or populations produce the most taxol, a crucial piece of information for selecting the best ones for biotechnological applications or plantations. We also hoped to determine the conservation status of wild stands of yews in the Philippines, as well as to procure samples for research groups that are studying the genetic and ecological aspects of yew biology. Since the intriguing results of tests against the HIV virus using prostratin were becoming well known by this time, the USDA extended our mandate to enable us to search for new species or populations of *Homolanthus* while we looked for yew.

Our pretrip research led us to an obscure book on the shelf of the Smith College library, *The Vegetation of the Philippine Mountains,* written in 1919 by William Brown, an associate of Elmer Merrill. His meticulous accounts were rich in all the kinds of data that help in planning a collecting trip, including the timing of monsoons and the altitude of various plant habitats. Brown also described the broad categories of forests found in the Philippines. At the lowest altitudes is the lowland Dipterocarp forest, a tropical rainforest with three stories of trees and a shrub and herb layer at the base. Some of these Dipterocarp trees can reach 130 feet in height and have been the source of Philippine mahogany lumber for hundreds of years. The lower montane, or mid-mountain, forest is found at altitudes of 3,300 to 8,200 feet. Evergreen oaks and laurels are the major component of this two-storied forest, with southern hemisphere conifers such as *Podocarpus* and *Agathis* found in this association. Finally, the lower montane mist forest, or mossy forest, is a high-altitude, single-layer assemblage of low-growing, gnarled, mossy trees bathed by daily mists or rain.

We acquired visual familiarity with *Homalanthus* by studying dried, pressed specimens in herbaria, noting the botanical characteristics of species that would help us distinguish them in the field. Field notes on herbarium labels give invaluable clues to location and often include altitude, associated species, local names of plants, and sometimes, more colorful information, as with the sample of *Homalanthus nutans.* Collected in the Solomon Islands by S. F. Kajewski in 1931, the notes included, "When a man has been infected by an evil spirit the sap of this tree is drunk to get rid of this spirit."

On the Ground in the Philippines

Our first stop in the Philippines was the National Museum in Manila, where we consulted with Philippine flora expert Dr. Domingo Madulid and put together our team. Our next destination was Mt. Pulog; at 9,607 feet it is the highest point on the northern island of Luzon. We drove north from Manila through a snarl of jeepneys, buses, cars, and motorbikes, at one point passing a 40-foot deep lahar flow six miles from its source, Mt. Pinatubo. Our party of four botanists and driver stayed that night in the mountain resort of Baguio, a city much damaged by a recent earthquake. The next day we began our ascent of Mt. Pulog on a road whose quality declined drastically as we hit steeper terrain. As if to further emphasize the power of nature in the Philippines, a front of thunderheads began to drop its moisture on us, making the last twenty miles a battle up the deeply rutted road, its clay soil slippery from the rain. Each time our efforts seemed doomed, we somehow cajoled our vehicle forward.

After reaching the entrance of Mt. Pulog National Park, we moved our gear into the cabin that serves as the park's headquarters and the camp for its solitary caretaker. While the torrent continued into dusk, we dried out under the tin roof, peering out at a *Homalanthus* plant across the stream that had once been a road. The clear light of morning showed the magnitude of settlement on the surrounding slopes: the forests of Benguet pine, *Pinus insularis,* had been intensively cut right up to the park's boundary, and the fields of the local Ifugao tribesmen surrounded our cabin.

Ironically, this degraded forest was ideal habitat for *Homalanthus,* and we had no problem finding several specimens of a large-leaf species, *H. megaphyllus,* a small tree with thick branches, large minaret-shaped buds, and a distinctive, rounded leaf with a red stem. We soon

MELVIN SHEMLUCK

A robust plant of Homalanthus megaphyllus *found near the headquarters of Mt. Pulog National Park.*

morning produced nothing, and as predicted, the rain began again at noon, reducing visibility to 75 feet. Melvin and I spent the afternoon walking along the edges of cabbage fields and up and down the crude paths that crisscrossed the slopes. It was evident that the forest had been severely depleted since yew was last collected on Mt. Pulog. Each hour of trudging past three-foot-wide pine stumps made us more depressed, and we began to talk of an epitaph for this population of yew.

We returned to the cabin dejected and prepared for defeat, but our gloom changed to joy when our Philippine colleague Ephrain greeted us with a fold of newspaper containing a sprig of yew. Not a thousand yards from the cabin our Ifugao guide had found five adult yew trees (up to 80 feet tall) and a trio of saplings on the edge of a cabbage patch. Once the guide confirmed that this was the plant we sought, he remembered seeing more of them farther north on the other side of the mountain.

We realized, however, that the day of the yew on Mt. Pulog is almost past: because it germinates and grows under a solid canopy, yew is found only in forests of long standing. *Homalanthus*, by contrast, rapidly establishes itself in recently disturbed areas—for instance, in clearcuts or canopy gaps. With farmers clearing the forests higher and higher up the mountains on Luzon, *Homalanthus* is enjoying a newfound prosperity.

To ensure broad genetic diversity, we wanted to collect from widely separated populations. After returning to Manila, we flew to Mindanao, the largest of the Philippines' southern islands, to seek out the yew and *Homalanthus* populations previously documented on Mt. Apo. Mindanao is also home to some rare endemic species of *Homalanthus*, and we hoped to locate some of these.

Mt. Apo is the highest peak in the Philippines; the only access is by foot. Our party of four botanists and three porters began the ascent

had a collection of a half-dozen samples of wood with corresponding cuttings for propagating back at the Smith Botanic Garden.

The cabin was sited at 7,500 feet, the point where the pine forest gave way to the moist, low, and dense mossy forest. Rather than carve out a trail through the heavy undergrowth, we stayed on the path to the summit of Mt. Pulog as we searched for yew trees and other *Homalanthus* species. Some of the species here were recognizable as common farther north in more temperate zones—spicebush *(Clethra luzonica), Berberis barandana, Deutzia pulchra, Ilex crenata* f. *luzonica*, and dense shrubs of *Rhododendron subsessile*. The most unusual collection of the day was a white-flowered epiphytic rhododendron unique for its thin needle-like leaves.

As we climbed higher the effects of the colder climate became evident in the stunted shrub-like forms of species that grew as trees lower down. At 8,700 feet, the woody flora disappeared altogether, giving way to a tussock grassland interspersed with a dwarf bamboo, *Arundinaria niitakayamensis*. At this point we were still 900 feet from the summit and the temptation to see the ocean from the top of the island beckoned, but our Philippine colleagues counseled that the rains would come again by noon. Since no *Homalanthus* or *Taxus* would be found above treeline, we retreated to search along other paths lower down. The rest of the

at the village of Kitapowan and walked upward through lush lowland forest. Towering above us, one spectacular tree, damar, *Agathis dammara,* had an eight-foot-wide trunk oozing a sticky, milky resin, which is the source of a resin used in varnishes.

Clumps of epiphytic orchids, some of them three feet across, cluttered the path, brought down by their own weight from the branches above. Some of the trees were so tall that the first branch was too high to identify, although tentative identification could be made from fragments of floral matter fallen on the path. Other plants, like the bizarrely primitive-looking screwpine *(Pandanus)* or the lush tree ferns, grew in the lower canopy layer and were unmistakable. We found one species of *Homalanthus* on the uphill climb—*H. populneus*—a solitary specimen of 45 feet that had sprouted near a treefall. After a grueling five-hour climb, we set up camp at 7,200 feet on the shores of Lake Venado. Again we found ourselves in a lush, mossy forest belt of southern conifers like *Dacrydium* and *Falcatifolium,* with the vivid scarlet blossoms of epiphytic vireya rhododendrons punctuating the green curtain.

Rain was pouring down again as we rested in camp and botanized around the lakeshore. Here we found trees more closely related to the southern flora: *Tasmannia, Leptospermum,* and *Pittosporum,* but no yew. From our camp we could see the north-facing slope of Mt. Apo. A fire had burned a considerable portion of its forest in 1986, and silvery dead trunks now rose out of a sea of ten-foot sawgrass. The lone path traversing this thicket seemed our only practical route for the next day's climb.

We set off early, aware now that the workday would be cut short by afternoon rains. The only prior collection of *Taxus* on Mt. Apo had been by the botanist Robbins in 1965, at an altitude of 7,500 feet. We moved upward nervously, fearing that Robbins had approached the peak from another direction, or that the fire had eradicated what may have been the only *Taxus* population on Mt. Apo. But at 7,300 feet we spotted a yew seedling, an eight-inch sprig in the moss on the edge of the path, and within the next 400 feet of altitude, we found an additional fifteen seedlings and saplings. These few plants had probably sprouted from seed deposited in the soil prior to the fire, and it seems unlikely that they will survive competition from the sawgrass or withstand the intensity of the full sun should they rise above it.

Although the specimens were too small to yield a sample for laboratory testing, we collected a few cuttings from each to root back at the Smith College greenhouses and to provide material for researchers working on other aspects of the yew. We tried one additional foray off-path in the direction of a promising ravine. But when clouds pumped up and postured threateningly, we turned back. Suddenly the rainy season began in earnest, with a downpour that dwarfed all previous storms. On the way back down the mountain we found one

MELVIN SHEMLUCK

While curious townspeople looked on, the author and other expedition team members prepared samples for the trip down the mountain.

more species of *Homolanthus, H. rotundifolius*, bringing our total to four.

Conclusion

Upon our return to the U.S. our *Taxus* samples were analysed for relevant medicinal compounds, and data concerning individual tagged trees was sent back to the Philippines. Should plantation culture become an option, these tags can identify elite trees. Cuttings were rooted at Smith College, and from these plants, material was supplied to other researchers working on the yew's taxonomy, biochemistry, and genetics.

Samples from our *Homalanthus* collection were sent to the Natural Products Branch of the National Cancer Institute to begin the long process of analysis and trial. Initial extracts showed significant activity against HIV cell lines, but further development has stalled for a variety of reasons; other plant compounds have shown more promise, as have certain non-plant-derived compounds. Although prostratin, unlike other compounds in its class (phorbol-esters), does not induce tumors, taint by association has dampened interest on the part of pharmaceutical firms. Dr. Paul Cox, the botanist who brought prostratin out of the rainforest, has suggested some plants may produce "gray pharmaceuticals," drugs of proven safety and efficacy that are not marketable in the Western world. Possibly prostratin may fall into this category, a low-cost, plantation-grown treatment option that offers an alternative to high-priced Western drug regimes. The colonizing nature of *Homalanthus* may make it an ideal subject for plantations in forested areas.

In the daily grind of plant-collecting, it is easy to fixate on the immediate goal, the plants themselves, and to forget that each collection, long shot though it is, may be the basis of a cure for thousands or millions of people. The renewed interest in botanical compounds makes collecting far afield possible, yet with each trip comes the realization that we may be chasing and bottling the last rays of light before an eclipse of uncertain dimension and duration.

Bibliography

Balick, M. J., and P. A. Cox. 1996. *Plants, People and Culture: The Science of Ethnobotany*. NY: Scientific American Library.

Brown, W. H. 1919. *Vegetation of the Philippine Mountains*. Manila: Bureau of Science.

Cox, P. A. 1993. Saving the Ethnopharmacological Heritage of Samoa. *Journal of Ethnopharmacology* 38(2–3): 181–188.

———. 1994. The Ethnobotanical Approach to Drug Discovery: Strengths and Limitations. In *Ethnobotany and the Search for New Drugs*, ed. D. J. Chadwick and J. Marsh (CIBA Foundation Symposium 185). NY: J. Wiley.

Cragg, G. M., et al. 1994. Ethnobotany and Drug Discovery: The Experience of the U.S. National Cancer Institute. In *Ethnobotany and the Search for New Drugs*, ed. D. J. Chadwick and J. Marsh (CIBA Foundation Symposium 185). NY: J. Wiley.

Gulakowski, R. J., et al. 1997. Antireplicative and anticytopathic activities of prostratin, a non-tumor-promoting phorbol ester, against human immunodeficiency virus (HIV). *Antiviral Research* 33(2): 87–97.

Gustafson, K. R., et al. 1992. A nonpromoting phorbol from the Samoan medicinal plant *Homalanthus nutans* inhibits cell killing by HIV-1. *Journal of Medicinal Chemistry* 35: 1978–1986.

Merrill, E. D., and M. L. Merritt. 1910. The Flora of Mount Pulog. *Philippine Journal of Science C. Botany* V(4).

Merrill, E. D. 1914. Notes on Philippine Euphorbiaceae, II. *Philippine Journal of Science C. Botany* IX(5).

Rob Nicholson manages the conservatories of the Smith College Botanic Garden, Northampton, Massachusetts. His article on cutleaf maples appeared in the summer 1997 issue of *Arnoldia*.

The Ecology and Economics of Elm Replacement in Harvard Yard

Peter Del Tredici

Two new Dutch elm disease-tolerant American elms have rekindled interest in restoring the species to the landscapes it once dominated.

These new selections of *Ulmus americana*—'New Harmony' and 'Valley Forge', recently introduced by the United States National Arboretum—represent an important horticultural breakthrough,[1] but some basic biological issues should be considered before any new plantings of the American elm are undertaken. The purpose of this article is to articulate these questions in economic as well as ecological terms in order to facilitate the decision-making process that many landscape architects, designers, and town managers now face concerning the use of American elms in historic landscapes.

The American Elm in History

The first question that should be asked is why this tree came to be so widely planted across eastern and central North America in the first place. The explanation can be found in the horticultural literature of the 1800s, particularly in a beautiful book by Lorin Dame and Henry Brooks that was published in 1890, *Typical Elms and Other Trees of Massachusetts.*[2] Profusely illustrated and written long before Dutch elm disease appeared in North America, it serves as a portrait of the American elm at the pinnacle of its landscape dominance. The authors made many important contributions to our knowledge of the American elm, but most significant is their documentation of a key fact: that the huge elms of the past reached their great size by virtue of rapid growth rate, rather than by great age. Other writers who described the American elm in the nineteenth century include F. A. Michaux (1819), A. J. Downing (1841), D. J. Browne (1846), F. J. Scott (1870), G. B. Emerson (1875), and C. S. Sargent (1890).[3] These authors make it clear that the American elm was widely planted for a number of reasons, only one of which was its great size and beauty. Other, more pragmatic reasons gleaned from the literature of the period can be summarized as follows:

- The American elm, a native species, was widely distributed throughout eastern and central North America, typically growing on moist bottomland or along disturbed roadsides.
- It was so easy to transplant that it could literally be ripped out of swamps and planted along roadways.
- It recovered well from the heavy pruning it received following these careless transplanting practices.
- It was highly adaptable, growing equally well on wet or dry sites.
- It grew very rapidly, averaging about a half-inch increase in caliper per year and reaching two to three feet in diameter within seventy years. Shade was in short supply in the nineteenth century, and the American elm provided it more quickly than any other tree.
- It shed its lower branches naturally, making it well suited for locations along heavily trafficked city streets and country roads.

Dutch Elm Disease

The Dutch elm disease fungus, along with its dispersal agent, the European elm-bark beetle, arrived in North America in 1930, hidden under the bark of European elm burl-logs that had

PETER DEL TREDICI

been shipped into the United States for making veneer.[4] The disease spread so rapidly and killed American elms so quickly that it seemed at first that the species was headed for extinction. Fortunately, this prediction has not come to pass. The species still thrives as a wild tree in wet woods and along streambanks throughout eastern North America.[5] As a landscape plant, however, the American elm is close to extinction. The grand old specimens, four to five feet in diameter, that once graced virtually every town common in New England have been replaced by trees that seldom reach more than eighteen inches across before succumbing to DED or some other disease.

Since the 1960s, there has been considerable publicity about various efforts to "save" or to "bring back" the American elm. Long-term approaches have involved either selecting DED-tolerant American elm cultivars or hybridizing American elm with other elm species that are DED-resistant. In contrast, short-term approaches focus on preserving existing specimens by spraying for the beetle, injecting infected trees with fungicides, and removing diseased limbs as quickly as possible. While these treatments have saved individual trees for up to twenty years, they are at best temporary solutions; the inevitable infirmities of old age are already catching up with older specimens.

PETER DEL TREDICI

American elms have long been valued for their exceptional growth rate. This 'Princeton' elm grew more than two meters in a single year. Jack Alexander, Arnold Arboretum propagator, points to the start of the current year's growth.

Case Study: The Harvard Elms

The American elm has been the mainstay of the Harvard Yard landscape for well over a hundred years. The trees have faced many threats during this time, but none has been as serious as the introduction of Dutch elm disease.[6] In 1979, when Harvard University began to implement an integrated elm protection program, there were 285 elms on campus. Most of them were American elms, but a number of English and European elms of uncertain identity were also mixed in. Most of the trees were about seventy or eighty years old when the protection program began. By 1994, after fifteen years of treatment, there remained only 165 elms, a mortality rate of 42 percent. Detailed figures do not exist, but the average cost of the total protection program for the Harvard Yard elms over the period is estimated at $25,000 a year, broken down roughly as follows:

- $14,000 for two sprays each year (one dormant oil and one foliage spray)
- $3,000 for fungicide injection each year
- $3,000 for fertilization every third year
- $5,000–$10,000 for pruning and removals

Over the fifteen-year period the total amount spent on the elms was approximately $375,000, or $100 per tree per year, in spite of which, mortality was at 42 percent after fifteen years. By extending these figures out, one can calculate the cost of elm maintenance over twenty years at roughly $500,000, with mortality approach-

Ulmus americana *'Princeton', a Dutch elm disease-tolerant American elm cultivar, has been growing on the northeast slope of Bussey Hill since 1935.*

ing 50 percent. By comparison, the annual cost for maintaining non-elm trees in the Yard is approximately $20 a tree.

Replacement Costs

In 1994 an elm replacement program was initiated.[7] The cost of planting 200 new trees in the Yard, most of them four to eight inches in caliper and ten to twenty feet tall, was $470,000, or $2,350 per tree, including a one-year maintenance contract and guarantee.

Essentially, the numbers show that the cost of planting 200 new trees was roughly equal to the cost of maintaining 285 elms for twenty years, of which only half will still be alive and the other half in a state of decline at the end of twenty years. To put it another way, twenty years of maintaining one large elm with only a 50-percent chance of survival costs the same as planting one new four-to-eight-inch caliper tree.

There is no absolute answer to the question of how much one should invest in an elm protection program, and in any case, the question should not be decided purely on an economic basis. Elm protection programs cannot save a tree forever, and in anticipation of the death of the elms, such programs should always be undertaken in conjunction with a program of planting other species of trees. It is clear that the high density of American elms that was seen in many cities and towns during the first third of the twentieth century should not be recreated.[8] Indeed, it was this high density that allowed the elm-bark beetle population to build up rapidly, leading to the epidemic spread of DED. One sees more elms surviving these days than in the past, not because trees are more tolerant of Dutch elm disease than before, but because the reduced elm population has resulted in lower elm-bark beetle populations. This in turn allows more elms to escape detection by their predators. Planting new trees of different species are

PETER DEL TREDICI

Just months after this photograph was taken, this hundred-year-old American elm, one of the last still standing on Boston's Commonwealth Avenue Mall, succumbed to a heavy wet snow that brought it crashing down onto cars and into townhouse windows.

The remnants of an allée of American elms tower over replacement plantings of Zelkova serrata *on the grounds of Phillips-Exeter Academy in Andover, Massachusetts. The zelkova has many merits, but neither in scale nor stature does it resemble the American elm.*

an investment in the future that softens the blow when a big elm dies, as it inevitably does.

Achieving Diversity

Unfortunately very few, if any, trees possess the combination of graceful form and great size of the American elm. The honey locust, *Gleditsia triacanthos*, comes about as close as any tree, but it grows much more slowly. *Zelkova serrata* has roughly the same shape but is much smaller. As Koller and Weaver point out, there is no perfect replacement for the American elm.[9] The key to successful substitution is to choose species with the same landscape impact or stature, regardless of whether they possess the American elm's structure.

Within the genus *Ulmus*, there are several potential candidates, but none are without some drawback. The ubiquitous Siberian elm *(U. pumila)*, for example, is highly resistant to DED but is very messy and graceless in form. The lacebark elm *(U. parviflora)* is a handsome tree, but much smaller than its American cousin. Some of the more recent hybrid elms (involving *U. davidiana, japonica,* and *wilsoniana*), may eventually prove to be excellent replacements, but they have not yet been thoroughly tested under landscape conditions.[10]

It must also be remembered that DED is only one of several diseases that kill American elms.[11] In particular, phloem necrosis and elm yellows can be lethal to many of the cultivars that have been selected for their tolerance to DED.[12] And the elm-leaf beetle, along with a host of other insects, had been killing elms long before DED arrived on the scene. If the American elm is to make a comeback in the modern American landscape—either as a hybrid or as a disease-tolerant selection—it should be used on an equal footing with other species, never as the predominant species in the landscape.

Another approach to replacing American

elms involves working within a single genus or family, which allows one to approach uniformity and diversity simultaneously. In the Tercentenary Theater part of Harvard Yard, for example, a grouping of legumes including *Cladrastis, Gleditsia, Gymnocladus,* and *Styphnolobium* (formerly *Sophora*), all share a characteristic arching trunk and flat-topped crown, but clearly differ in other aspects of their habit. One can also group different oak species to achieve a measure of uniformity amidst diversity. In the oldest section of the Yard, a grouping of oak species includes *Quercus rubra, palustris, phellos, coccinea, alba, bicolor,* and *acutissima.*

The advantages of increased species diversity can be summarized as follows:

- It offers a measure of protection against an epidemic spread of insects or of fungal and bacterial diseases.
- It allows one to match different microclimates on the site with the most appropriate species.
- It provides greater variation in flower and foliage displays, making a walk across campus a more interesting and potentially a more educational experience.

Conclusion

The desire to restore the American elm to its former status as the primary street tree in the East is very strong. But if "restoring" a given historic landscape means replanting the American elm—or any of its disease-tolerant selections or hybrids—at the density it occupied historically, then it is a mistake. In the popular literature on elms, the unspoken assumption seems to be that if we could only conquer Dutch elm disease, then we could easily recreate the grand, elm-lined streets of the past. This idea is biologically unsound. Because of the dynamic nature of the interaction between host and predator, "disease tolerance" is always a relative phenomenon, not a fixed genetic trait; total immunity is unattainable. Historical accuracy and aesthetic tastes notwithstanding, it is in no one's interest to bring the American elm back to its former position of landscape preeminence.

Endnotes

[1] United States National Arboretum Plant Introduction Announcement, *Ulmus americana* 'Valley Forge' and 'New Harmony' (January, 1997).

[2] An excerpt from *Typical Elms and Other Trees* appeared in *Arnoldia* (1982) 42(2): 49–59.

[3] F. A. Michaux, "*Ulmus americana,*" in *The North American Sylva,* vol. 3, tr. by A. L. Hillhouse (Paris and Philadelphia, 1819); A. J. Downing, *A Treatise on the Theory and Practice of Landscape Gardening,* 9th ed. (NY: Orange Judd, 1873); D. J. Browne, *Trees of America* (NY: Harper & Bros, 1846); F. J. Scott, *The Art of Beautifying Suburban Home Grounds of Small Extent* (NY: D. Appleton, 1870); G. B. Emerson, *A Report on the Trees and Shrubs Growing Naturally in the Forests of Massachusetts,* 2nd ed. (Boston: Little Brown, 1875). C. S. Sargent, "*Ulmus americana*", in *Silva of North America,* vol. 7. (Boston: Houghton Mifflin, 1890).

[4] Berton Roueché, "Profiles: A great green cloud," *The New Yorker* (July 15, 1961), 35–53; Donald C. Peattie, *A Natural History of Trees,* 2nd ed. (Boston: Houghton-Mifflin, 1964).

[5] R. M. Burns and B. H. Honkala, eds., "*Ulmus americana,*" *Silvics of North America,* vol. 2, Hardwoods (USDA Forest Service Agriculture Handbook 654, 1990).

[6] J. Shaw, "Every tree doomed," *Harvard Magazine* (1994) 96(4): 46–53.

[7] Ibid; M. Van Valkenburgh and P. Del Tredici, "Restoring the Harvard Yard Landscape," *Arnoldia* (1994) 54(1): 2–11.

[8] J. O. Dawson and M. A. Khawaja, "Change in street-tree composition of two Urbana, Illinois, neighborhoods after fifty years: 1932–1982," *Journal of Arboriculture* (1985) 11(11): 344–348.

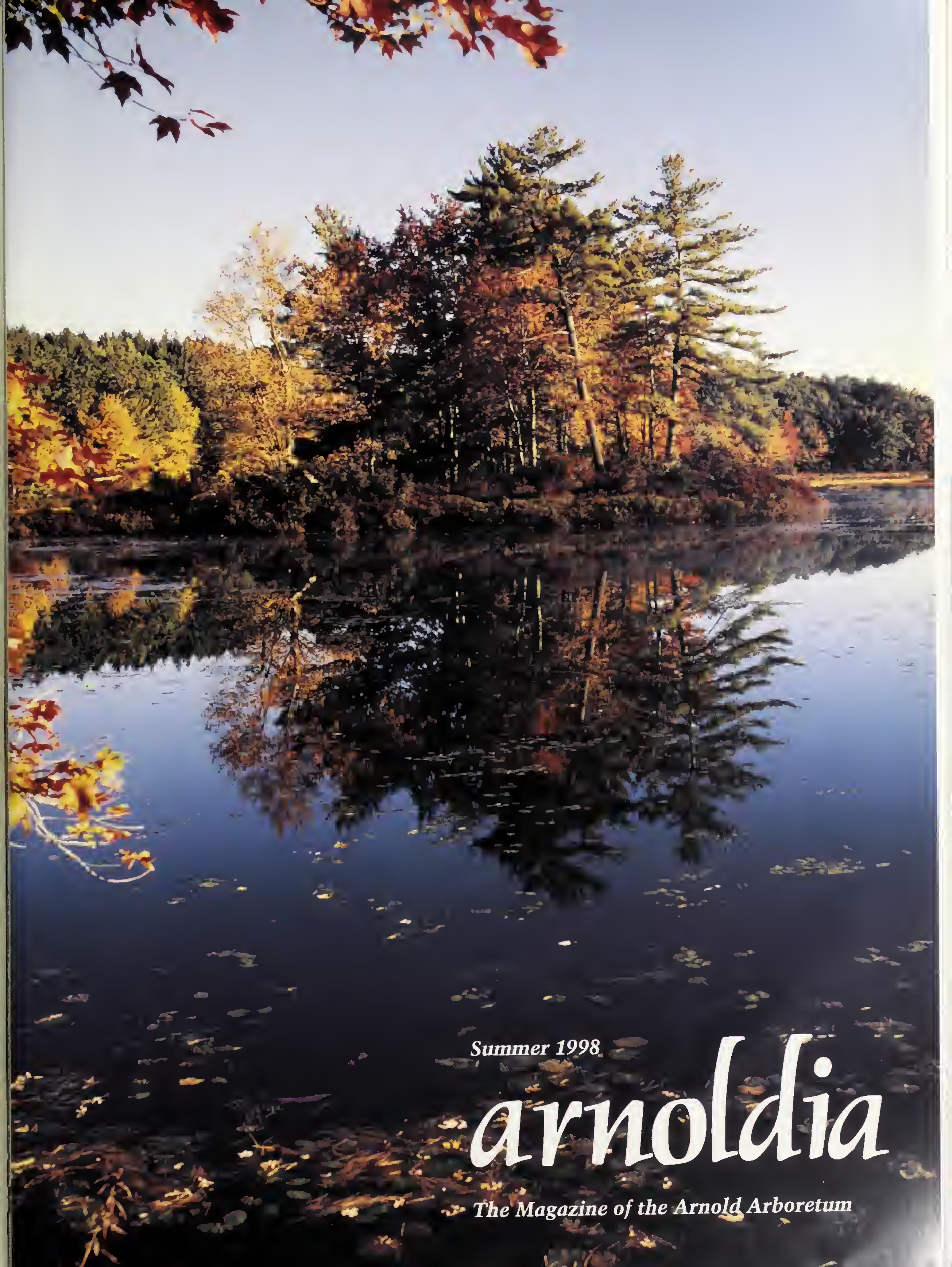
[9] G. L. Koller and R. E. Weaver, Jr., "Replacing the American Elm: Twelve Stately Trees," *Arnoldia* (1982) 42(2): 88–100.

[10] Michael Dirr, *Manual of Woody Landscape Plants,* 4th ed. (Champaign, IL: Stipes, 1990); F. S. Santamour, Jr., and S. E. Bentz, "Updated checklist of elm *(Ulmus)* cultivars for use in North America, *Journal of Arboriculture* (1995) 21(3): 122–131; A. M. Townsend et al., "Variation in response of selected American elm clones to *Ophiostoma ulmi,*" *Journal of Environmental Hoticulture* (1995) 13(3): 126–128; G. Ware, "New elms for urban landscapes," *Morton Arboretum Quarterly* (1995) 31(1): 1–9.

[11] Sinclair et al., *Diseases of Trees and Shrubs* (Ithaca, NY: Cornell University Press, 1987).

[12] Santamour and Bentz, op cit.

Peter Del Tredici is Director of Living Collections at the Arnold Arboretum.


Summer 1998
arnoldia
The Magazine of the Arnold Arboretum

arnoldia

Volume 58 Number 2 1998

Arnoldia (ISSN 004-2633; USPS 866-100) is published quarterly by the Arnold Arboretum of Harvard University. Second-class postage paid at Boston, Massachusetts.

Subscriptions are $20.00 per calendar year domestic, $25.00 foreign, payable in advance. Most single copies are $5.00. Remittances may be made in U.S. dollars, by check drawn on a U.S. bank; by international money order; or by Visa or Mastercard. Send orders, remittances, change-of-address notices, and all other subscription-related communications to: Circulation Manager, *Arnoldia*, The Arnold Arboretum, 125 Arborway, Jamaica Plain, Massachusetts 02130-3500. Telephone 617/524-1718; facsimile 617/524-1418; e-mail arnoldia@arnarb.harvard.edu.

Postmaster: Send address changes to
Arnoldia Circulation Manager
The Arnold Arboretum
125 Arborway
Jamaica Plain, MA 02130-3500

Page

2 **AN ECOLOGICAL HISTORY OF MASSACHUSETTS FORESTS**
John O'Keefe and David R. Foster

4 I. Dynamics in the Postglacial Era

8 II. Disturbance Prior to European Settlement

11 III. Changes After European Settlement

26 IV. Present Conditions and Future Prospects

32 **CASE STUDIES IN FOREST HISTORY AND ECOLOGY**

33 How Land Use Determines Vegetation: Evidence from a New England Sand Plain
Glenn Motzkin and David R. Foster

35 Forest Response to Natural Disturbance Versus Human-Induced Stresses
David R. Foster, John Aber, Jerry Melillo, Richard D. Bowden, and Fakhri Bazzaz

41 Ecosystem Response to an Introduced Pathogen: The Hemlock Woolly Adelgid
David A. Orwig and David R. Foster

Front cover: Harvard Pond, Petersham, Massachusetts. Photograph by David R. Foster.

Inside front cover: Al Cline, director of the Harvard Forest, 1939–1946, leans against a windthrown white pine that was uprooted in the 1938 hurricane. From the Harvard Forest Archives.

Inside back cover: Dead white pine snag on the Pisgah tract of the Harvard Forest in southern New Hampshire. This large snag is a remnant of the old-growth forest that blew down in the 1938 hurricane and is surrounded by the vigorous growth of a new, regenerating forest. Photograph by David R. Foster.

Back cover: Aerial photograph of the Prospect Hill tract of the Harvard Forest taken by David R. Foster in 1995. The fire tower rises above conifer and hardwood forests.

LAURA WULF

Old hemlock forest in the Slab City tract of the Harvard Forest.

An Ecological History of Massachusetts Forests

John O'Keefe and David R. Foster

The forests of Massachusetts present a history of almost continual change, albeit change that has varied greatly in scale, rates, and causes through time. The importance of human disturbance relative to natural disturbance has steadily increased—gradually at first, as aboriginal activity expanded to include agriculture, and then rapidly since European settlement. Just as the variety, frequency, and extent of human disturbance have increased through time, they can be expected to continue increasing and changing into the future.

European settlement in the seventeenth and eighteenth centuries brought a dramatic transformation as much of the land was deforested and farmed and the remainder was logged, grazed, or burned. Since the mid-nineteenth century, agriculture and forest use have declined, forest area and age have increased, and the land has become more "natural" than at any time postsettlement. But despite the natural appearance of much of the modern landscape, a legacy of intensive past use remains in vegetation structure and composition, in landscape patterns, and ongoing dynamics. Consequently, an understanding of the history of human influence must be an integral part of ecological study and a critical component of conservation planning and resource management.

For millennia our forests had been evolving into the landscape that greeted the settlers. One reasonable start for our forests' history is the end of the last glacial period, more than 13,000 years ago.

ICE AGE
13,000 Tundra
11,500 Spruce woodland and forest
10,000 Human arrival
9,500 Pine forest
8,000 Mixed deciduous forest
5,000 Hemlock decline
3,000 Arrival of chestnut trees
1,000 Native American agriculture
250–350 European settlement
150 Peak of agricultural clearing
85 Chestnut blight
60 1938 hurricane
PRESENT

Approximate chronology of important events in the development of Massachusetts' forests, given in years before present.

I. Dynamics in the Postglacial Era

Over 15,000 years ago, at the peak of the last glaciation, most of present-day Massachusetts was covered by ice up to a mile thick. Cape Cod and the offshore islands—Nantucket, Martha's Vineyard, and the Elizabeth Islands—consist largely of what geologists call moraines, piles of debris accumulated at the front of the advancing ice sheet and left behind when the glaciers finally melted. The advancing glaciers not only smoothed and shaped the landscape by scraping and plucking the bedrock as they advanced, they also left behind a layer of ground-up rock, or *till*, which has since evolved into soil. As the glaciers melted, the tremendous volume of water produced seasonal streams that carried and sorted much of this material and deposited sands and gravels wherever they slowed.[1] The soils of Massachusetts are a product of this massive natural engineering, later supplemented by organic material from the vegetation that eventually covered the landscape. Along major rivers fine silt was deposited when the rivers overflowed their banks in spring; in some depressions a surplus of moisture allowed thick layers of peat or muck to develop. The resulting pattern of soil types has strongly influenced the type and distribution of trees and forests.

Of course, during the glacial period, there were no forests in Massachusetts: The modern tree species of New England were restricted to favorable locations called *refugia* south of the glacial zone, presumably scattered across the southern Appalachians and the eastern coastal plain. The huge quantities of water trapped on land as glacial ice had once been seawater; consequently, sea level was several hundred feet lower than at present, leaving vast areas of continental shelf off the present-day East Coast exposed as refugia as well. The forests in these various refugia contained species mixtures unlike any we are familiar with today. As the climate warmed and the glaciers melted, the trees began their migration north at rates determined by the method of seed dispersal and the climatic tolerance of each species.

We are fortunate to have a record of this postglacial migration in the form of pollen preserved in sediments at the bottom of lakes and ponds and below many wetlands. Each year pollen from plants is carried away on the wind. When it lands on the water of a pond or lake, it sinks to the bottom, and along with other wind-borne material is incorporated into the sediments. These sediments form a chronological sequence of layers, the oldest at the bottom, which scientists can recover as a thin cylinder or core of mud. Each layer in the core can be dated using radioisotopes, and since pollen is extremely resistant to decay—the pollen of different plants can be identified at least to genus and in some cases to species—the presence and relative abundance of different types of pollen at each layer enables paleoecologists to reconstruct the major vegetation changes at a site.

The pollen diagram for the Harvard Forest Black Gum Swamp (page 6) shows changes in vegetation over time that are typical of sites across Massachusetts. As the glaciers melted and the climate warmed, a period of tundra is followed by boreal (northern conifer) forest, succeeded in turn by pine forest with rapidly increasing amounts of several deciduous species (birch, oak, beech) by 8,000 years ago. Although mixed deciduous forests have been dominant for the last 8,000 years, the mixture of species has changed continually during that period, and these changes can tell us much. Species have behaved quite independently, presumably migrating to Massachusetts from different locations at different rates, each species responding in its unique fashion to the various combina-

Alders, bearberry, and other pioneer vegetation follow a receding glacier in Alaska.

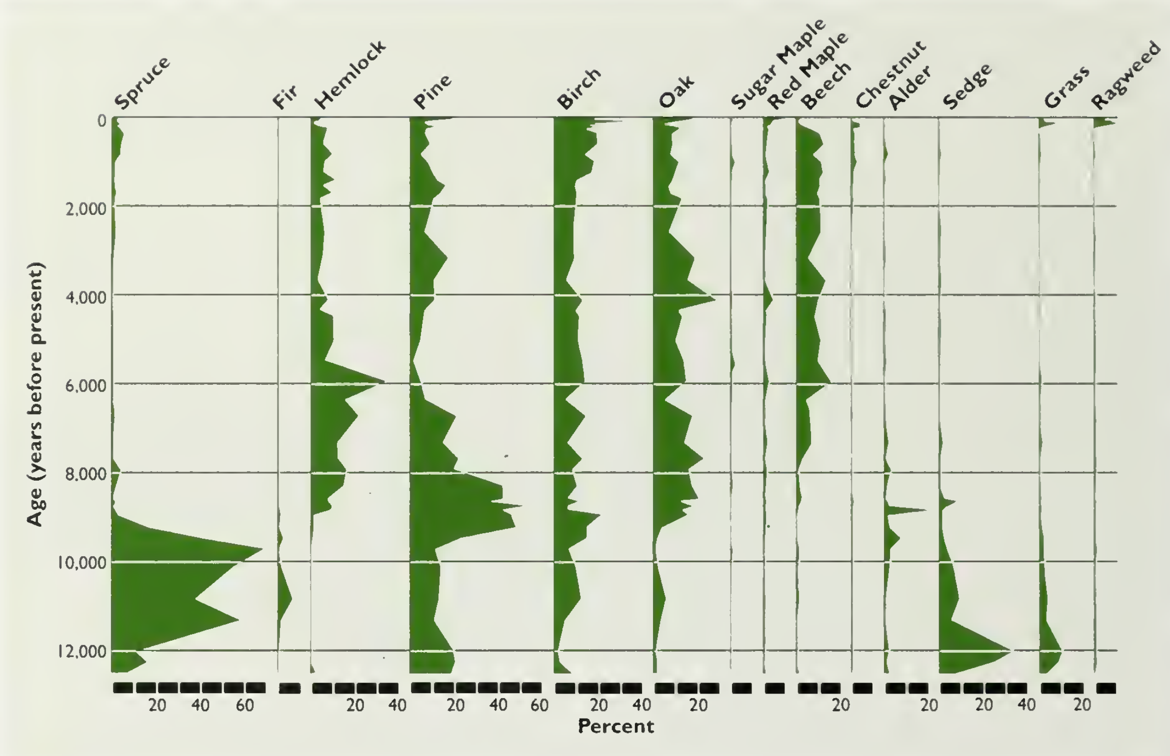
tions of climatic, soil, biotic, and historical factors found in the area. The major influences on these changes are long-term climate change, migration rates of individual species, and natural disturbance processes.

Population dynamics of selected species help us understand these processes. Hemlock increased rapidly in importance after its arrival about 9,000 years ago. A little less than 5,000 years ago, it decreased dramatically in a very short time, then slowly recovered. This sudden decline, seen in pollen records throughout the Northeast, has been attributed to a severe outbreak of insects or disease that greatly reduced hemlock populations for nearly 1,000 years.

Regional pollen analyses suggest that temperatures during the period from 8,000 to 5,000 years ago were milder than those of the last 4,000 years.[2] It was during this warm period that many tree species now common in Massachusetts migrated into the area, with some species extending well north of their current ranges. At a number of sites, fire frequency, indicated by charcoal in sediment cores, was also greater than in the more recent period.[3] The increase in spruce pollen over the last 2,000 to 3,000 years was probably caused by more recent cooling. All these changes in forest communities were complex: while spruce, a northern species, increased—evidently in response to gradual cooling—chestnut, a southern species, was also migrating north across Massachusetts. In fact, chestnut is the most recent arrival in the pollen record, appearing less than 3,000 years ago, much later than the other important deciduous species that occur in the region today.

The Natural Environment

The distribution of forest types across Massachusetts during the period preceding European settlement was controlled by the physical geography, or physiography, of the landscape; the



Pollen diagram from the Black Gum Swamp at the Harvard Forest in central Massachusetts depicting the major changes in the vegetation over the past 12,000 years. Tundra communities were replaced by boreal forest dominated by spruce until approximately 9,200 years before present (B.P.) when pine and other tree species became important.

Changes in the relative abundance of species resulted from climate change, species migrations, disease (hemlock decline at about 5,000 B.P.), and fire until 250 to 300 years B.P., when European settlement resulted in major deforestation and the increase in agricultural weeds, herbs, and early successional species.[4]

underlying geology; and the frequency of disturbances such as windstorm and fire. Massachusetts, excluding Cape Cod, is roughly rectangular, 125 miles (200 km) east to west and 50 miles (80 km) north to south. Today it receives approximately 40 inches (100 cm) of precipitation annually, distributed fairly evenly throughout the year, with a mean annual temperature that ranges from a mean of several degrees Fahrenheit below freezing in January to about 70 degrees in July, and averages nearly 50 degrees over the year.

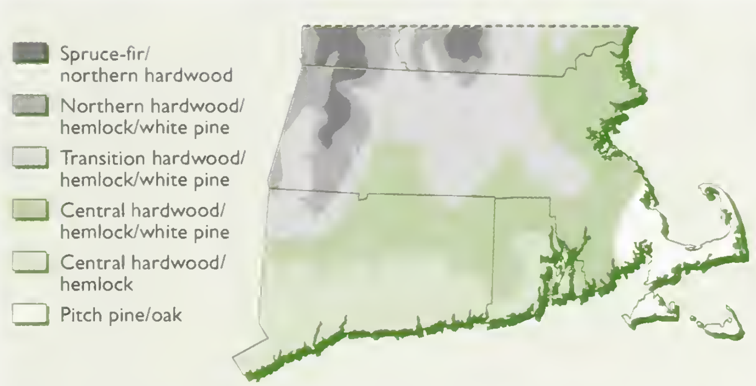
Within a relatively small, compact area, Massachusetts contains six broad physiographic regions: the coastal lowlands, the central uplands, the Connecticut River valley, the Berkshire Mountains, the Berkshire valley, and the Taconic Mountains. The geologic substrate varies across the state. Except for parts of the Connecticut River valley, the Taconic Mountains, and the Berkshire valley, the soil is acidic, poor in nutrients, and shallow with patches of exposed bedrock. Elevation generally increases from east to west, reaching a maximum at Mt. Greylock in the Berkshires (3,487 ft [1060 m]). These are the physiographic and geological conditions that interact with climate to produce vegetation zones sometimes referred to as ecoregions.

Within Massachusetts natural vegetation zones are largely determined by climate, which in general varies with elevation except in areas near the moderating influence of the ocean. Southeastern Massachusetts, all of Cape Cod,

Map of southern New England depicting the major physiographic regions. From east to west they are coastal lowlands, central uplands, Connecticut River valley, Berkshire Mountains, Berkshire valley, and Taconic Mountains.[5,6]

and the offshore islands fall within the pitch pine-oak zone. This vegetation type, occurring on sandy and gravelly soils laid down as glacial moraines or outwash deposits, is characterized by drought-tolerant and fire-adapted species, including pitch pine, scrub oak, and huckleberry. This type also occurs on scattered outwash deposits in inland Massachusetts. The remainder of the coastal lowlands, the southern central uplands, and the southern Connecticut River valley fall within the central hardwood-hemlock-white pine zone. This vegetation type represents the northern extension of the oak-hickory dominated forests of the central Appalachians and the Middle Atlantic States.

North and west of the central hardwood zone we generally find the transition hardwood zone, which also extends up the major river valleys in the western part of the state. This zone is characterized by increasing amounts of species found farther north, such as yellow birch, black (or sweet) birch, sugar maple, and beech, with less oak (especially white oak) and with paper birch occurring on heavily disturbed sites. The higher elevations in the Berkshire and Taconic mountains and the extreme northern border of central Massachusetts fall within the northern hardwood and spruce-fir zones. The spruce-fir zone, in which red spruce is the dominant conifer, is restricted to the highest elevations, generally above 2,000 feet, while the northern hardwood zone occurs just below the spruce-fir zone and has hemlock and white pine as its dominant conifers. Both zones have mixtures of hardwoods dominated by sugar maple, yellow birch, beech, and red maple.



The major forest vegetation zones in southern New England. Sandy glacial deposits, found on Cape Cod and in extreme southeastern Massachusetts, support a dry forest of pitch pine and scrub oak. Transition hardwood forest dominates the central uplands and much of the Connecticut River and Berkshire valleys, with northern hardwood forest on the higher elevations in the Berkshires and Taconics and spruce-fir forest on the highest elevations.[7]

II. Disturbance Prior to European Settlement

Natural Disturbance

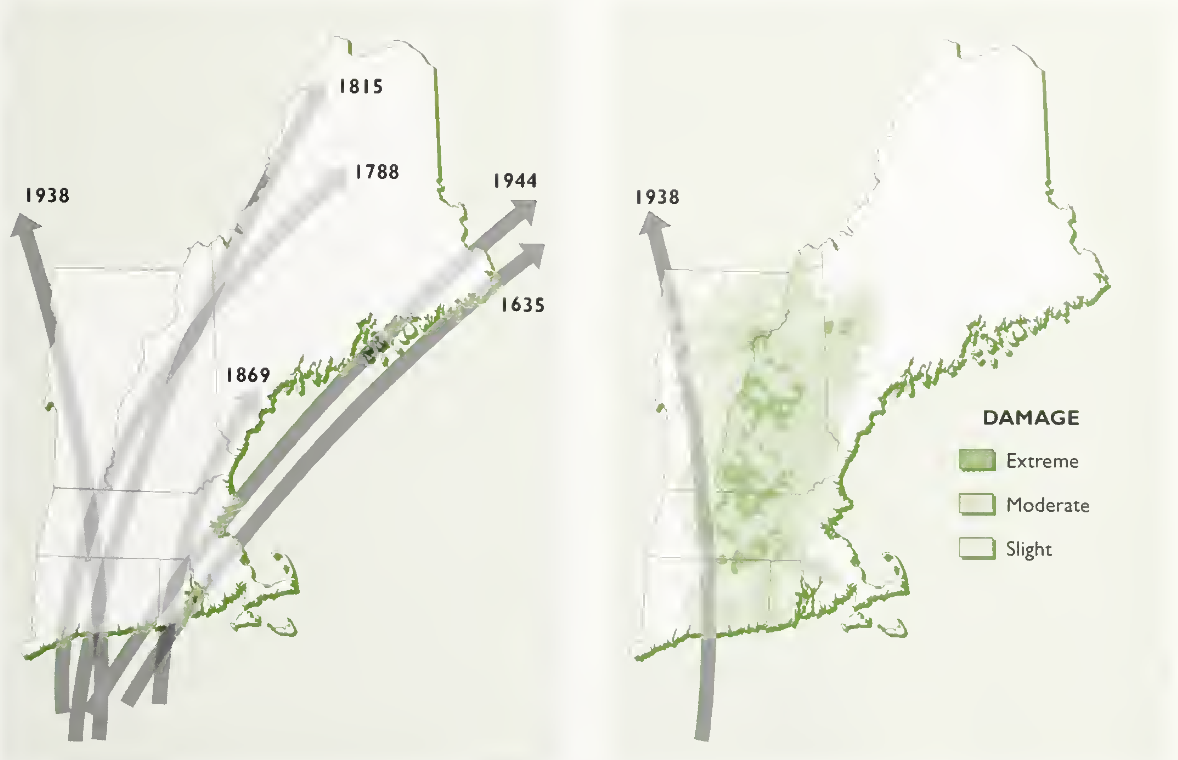
The major natural disturbances affecting Massachusetts forests include windstorms, pathogens (insect and diseases), and fire. Evidence of past storms may persist for as long as a thousand years in the pits and mounds often found in our forests,[8,9] but these microtopographic features offer no information about the frequency, intensity, and distribution of storms, which vary with changing climatic conditions. However, if, as seems likely, storm patterns have remained stable in Massachusetts over the postglacial period, we can infer trends from observations over the past few hundred years.

Two different types of windstorms cause significant damage to Massachusetts forests: tropical storms, or hurricanes; and downbursts, or microbursts—sudden, straight-line winds, often from the northwest, associated with severe thunderstorms and occasionally accompanied by tornadoes. Downburst winds are probably the dominant wind disturbance in the Berkshires and western Massachusetts. They continue east across central Massachusetts and become less important in areas near the coast under the stabilizing influence of maritime winds. While commonly confined to small areas, the potential destructiveness of these winds was demonstrated in July 1995, when hundreds of thousands of acres of forest from the Adirondack region of New York into western Massachusetts were severely damaged by an extremely large and long-lived downburst front.[10]

Tropical storms represent the most important wind disturbance in central and eastern Massachusetts. Historical evidence indicates that hurricanes may affect central and eastern areas approximately every hundred years, with the Cape and islands affected more often. The strongest winds in these large, counterclockwise-rotating storms are on the easterly side, as illustrated by the catastrophic storms of 1815 and 1938. These storms produced the greatest damage on south- and east-facing hillsides while steep north and west slopes were protected from the strongest winds.[11] Western exposures and ridges, on the other hand, are prone to selective damage from the more patchily distributed microburst winds associated with severe thunderstorms.

The only strong evidence of pathogenic disturbance in the paleoecological record is the widespread hemlock decline nearly five thousand years ago. The rapidity and extent of this decline, not associated with declines in other species or identifiable climatic change, points to a species-specific pathogen as the cause. Hemlock remained at low population levels for nearly a thousand years. The extent of its eventual recovery differed across the region. At many sites, hemlock gradually approached its predisturbance abundance between a thousand and fifteen hundred years later.[12] At other sites, it never fully regained its former importance, presumably because of competition with recently immigrating species or slight climatic changes over the intervening period. Of course, this event offers many comparisons with the human-transported pathogens (gypsy moth, chestnut blight, hemlock woolly adelgid) that our forests are coping with today.

Fire, like windstorms, probably differed significantly in its impact across Massachusetts as a result of differences in climate, fuel type and abundance (which varies by vegetation type), and ignition sources (lightning and aboriginal human populations). When we look at the impacts of fire, we encounter the earliest strong evidence for human influence on Massachusetts forests. Charcoal in sediment cores indicates that fires were less frequent and therefore less important in the Berkshires than in southeast-



Paths of the major hurricanes that have impacted New England from 1600 to the present are shown on the left. On the right is the damage inflicted on forests in the region by the 1938 hurricane. Approximately three billion board feet of timber were windthrown by the storm, more than six hundred lives were lost, and damage costs exceeded a hundred million dollars.[14,15]

ern Massachusetts and on Cape Cod.[13] The droughty, sandy soils of the latter areas supported a highly fire-prone vegetation largely dominated by pitch pine, scrub oak, other oaks, and huckleberry. Pitch pine, like all conifers, contains resins in its needles that make it much more flammable than broadleaf, deciduous trees. Huckleberry, although a broadleaf, deciduous species, also contains resins in its leaves and therefore creates a very flammable understory. At the same time, this type of vegetation is highly fire-adapted. All the oaks, especially scrub oak, are prolific sprouters following injury. Pitch pine is unique among Massachusetts' native conifers in possessing dormant buds beneath the bark and near the base of its trunk that enable the tree to sprout and survive if the main stem is severely damaged by fire. Moreover, the cones of pitch pine tend to be *serotinous*, which means they may remain closed with seed inside until the heat from a fire triggers an opening mechanism to release the seeds onto the recently burned landscape. Although pitch pines in Massachusetts rarely exhibit this behavior today, it is commonly observed in the frequently burned New Jersey pinelands.

The northern hardwood species—sugar maple, beech, and yellow birch—while capable of sprouting, tend to have thinner bark that provides less protection from understory fires. Hemlock, a major associate in the northern hardwood forest, is also thin-barked as well as slow-growing, long-lived, and incapable of sprouting. Therefore, where these species were dominant, we can conclude that fires were not as frequent or severe as in southeastern Massachusetts. Moreover, during the growing season broadleaf foliage normally holds enough water to be nonflammable. This moisture tends

to limit the fire season in our broadleaf forests to spring and fall, when the fallen dry leaves often burn in surface or brush fires. In fact, the combination of these factors led some to nickname the northern hardwood forest "the asbestos forest."

Aboriginal Human Impact

American Indian populations migrated into Massachusetts shortly after the trees, some ten thousand years ago, but their populations remained quite low until four or five thousand years ago. Some researchers have speculated that the hemlock decline of about that time and the subsequent increase in species such as oak and hickory, which produce abundant large nuts edible by both wildlife and humans, may have contributed to the increase in aboriginal populations.

Areas of concentrated aboriginal human populations in southern New England during the Late Woodland period (1000 B.P.–400 B.P.) immediately preceding European settlement. Populations were concentrated along major river valleys, the coast and the larger islands of Nantucket and Martha's Vineyard, and the lower reaches of broad upland areas.

Archaeological evidence indicates that human populations—like fires—were more numerous in the eastern than in the western part of the state during the period four hundred to a thousand years ago, with settlements also found along the major river basins.[15] There is little evidence that these populations cleared extensive areas for agriculture. It is more likely that they created a patchwork of recently cleared areas, abandoned fields, and village sites in a matrix of intact forest. Population density (and presumably human impact on the forest) gradually decreased moving away from the coast,[16] from a high of up to fifty people per square mile on Nantucket and Martha's Vineyard, to four to ten per square mile in inland eastern and southeastern Massachusetts and the Connecticut River valley. It is unlikely that permanent settlements were made in the upland Berkshires.

Interestingly, the areas of high population density shown here match the distribution of the central hardwood and pitch pine-scrub oak forest zones seen on page 7. These are the forest types most suitable for burning. Although extensive debate continues regarding the frequency, extent, and broad-scale impacts of aboriginal burning, there is general agreement that these populations did burn forests to create fields and to rejuvenate understory browse for deer and other animals they hunted.[16,17] No doubt this burning was largely restricted to dry areas where most vegetation was already adapted to fire, but it also intensified these conditions by reducing any fire-sensitive species that may have been present.

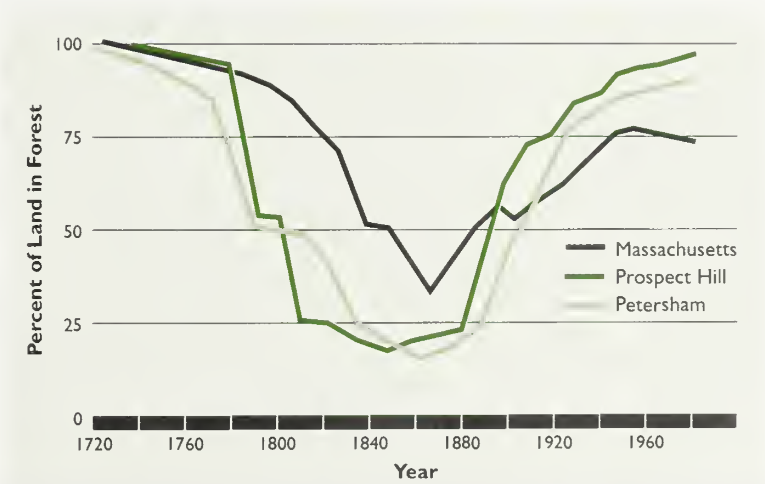
III. Changes After European Settlement

The Colonial Period

European settlement spread through Massachusetts at uneven rates. The coastal counties Essex, Suffolk, Norfolk, Plymouth, and Bristol were largely settled by 1675, as was the Connecticut River valley, with settlers moving northward from settlements in the Springfield area that dated from the early 1600s. Concentrated in the coastal lowlands and major river valleys, these early settlement zones corresponded closely with the areas where aboriginal practices had most affected the forests. Settlement spread westward from the coast into Middlesex and Worcester counties in the late seventeenth and early eighteenth centuries and into the foothills of the Connecticut River valley during the same period. In 1725 Massachusetts began using land grants to pay off debts, especially for military service,[18] which encouraged settlement in the central upland areas. The last areas to be settled, from the second half of the eighteenth century into the beginning of the nineteenth century, were the Berkshire Mountains and the northernmost portions of the central uplands.

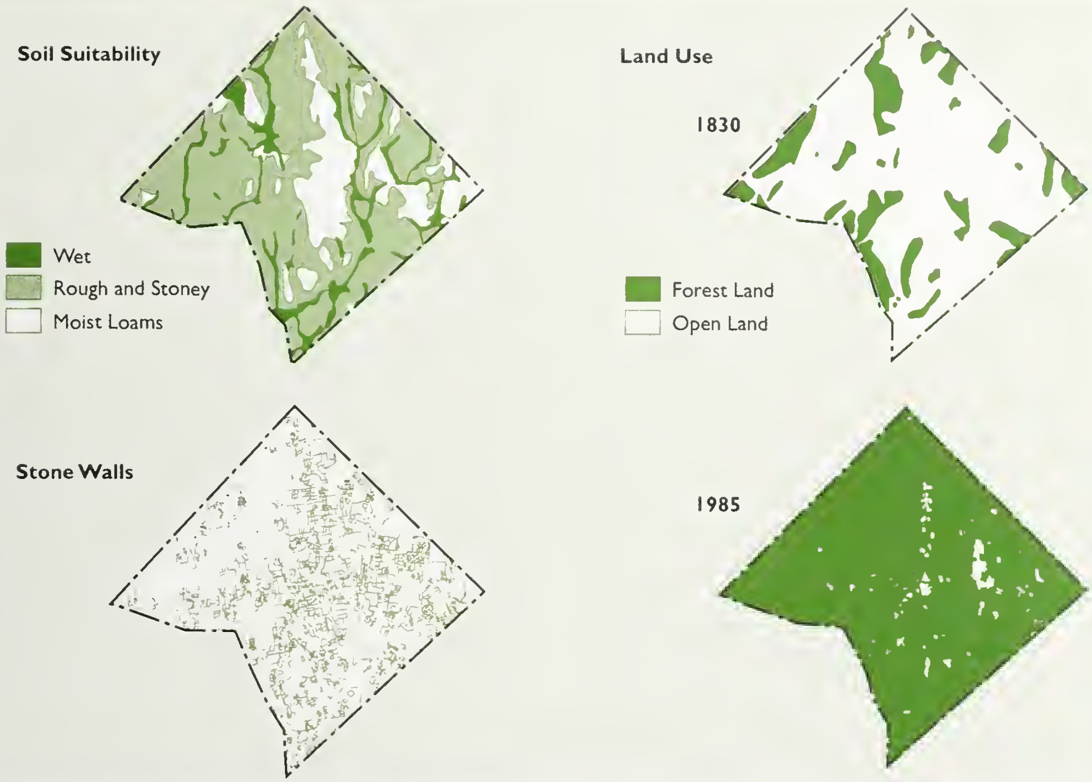
Forest clearing was initially quite slow, for reasons that included the lack of markets for excess production and a town organization based on the European model of a centralized settlement and common field system.[16,19] More than a hundred years after its settlement in 1635, Concord was still more than fifty percent forested. This rate of deforestation, about 0.4 percent a year, was typical of towns in the seventeenth century.[16] A shift to a town pattern of dispersed settlement and individual ownership of private land, with all land in the township distributed, led to much more rapid deforestation toward the middle of the eighteenth century. Rates of 0.8 percent to 1.0 percent per year were common in the second half of the eighteenth century both in older towns like Concord and new ones like Petersham.

This acceleration in deforestation coincided with a shift toward a market economy, partly driven by a developing beef trade with the West Indies. Cattle were suitable for remote hilltown farms during this period because they could be walked to market on the rudimentary roads that precluded the long-distance transport of most products. The difficulty of transport also partly explains the methods most commonly used to clear the forest: girdling the trees and leaving them in place to fall apart slowly, or cutting and burning them.[16] Except where water transport



Changes in the percentage of the land area covered by forest during the historical period in the state of Massachusetts, town of Petersham, and the Prospect Hill tract of the Harvard Forest.[20]

HARVARD FOREST ARCHIVES



These maps of the township of Petersham, Massachusetts, depict soil suitability and stone walls, on the left, and on the right, forest cover in 1830 and 1985. Stone walls and agricultural land are concentrated in areas of more productive soil.[21]

was available, trees had value as lumber or firewood only locally. Potash, a relatively more compact and transportable product, was probably the major marketable product from the trees of these early farms.

Pasture was the most suitable use for most of Massachusetts, since the rockiness of most areas made preparing land for tillage a long and backbreaking chore. It has been said that it took two generations to clear upland farms for plowing, the first to remove the trees and the second to remove the stones. The massive stone walls surrounding abandoned fields across the state attest to the effort required by the second task. And yet the great number of rocks scattered throughout the remaining pastures and second-growth woods suggest that the majority of the landscape was never tilled, but rather grazed or at most mowed. The principal exceptions, of course, were the major river valleys, where postglacial alluvial deposits provided excellent tillage once the trees were removed. These areas are notable for their lack of stone walls.

In upland areas, hilltops were often selected for village centers and initial clearing for agriculture because they had good drainage and

---

Above left, presettlement forest; below, initial clearing and subsistence farming, 1740. Most human disturbances prior to European settlement were infrequent and scattered. Nonetheless, the forest communities that the settlers encountered had evolved under dynamic conditions and had been in place only a relatively short time.

These images are from the dioramas (three-dimensional models) in the Land-Use History series on permanent display at the Fisher Museum of Forestry, Harvard Forest, Petersham, Massachusetts. They depict typical changes in the upland Massachusetts landscape, from initial European settlement through the 1930s (when they were constructed). Other dioramas in this remarkable series depict forest management and conservation practices.

relatively few stones. Except for the broad river valleys, inland lowlands often offered poor drainage and a shorter growing season. Colonists commonly evaluated land quality on the basis of topography and on their knowledge of the site preferences of different tree species and forest types.[16,19]

Initially, a farmer might clear six to eight acres over the course of several years. When tilled, this initial clearing could support a typical family of five to seven.[16] During this period the dominant economic base of rural Massachusetts was low-intensity agriculture combined with artisanship. Few individuals provided for all their needs through their own labor, but through cooperation and exchange, townships could be largely self-sufficient. Towns supported a range of artisans, shops, mills, and tanneries. Roads provided internal circulation but relatively poor access to external markets. At the same time, coastal communities were developing extensive fishing, manufacturing, and shipping industries, exploiting local forests for shipbuilding materials and export products. By the mid-1700s Salem was the most prosperous port in the country and a center of worldwide trade.

Agricultural Period

The period from the late 1700s through the first half of the nineteenth century saw a major transformation of the economy, social structure, and landscape of Massachusetts.[22,23,24] The rural economy underwent a shift from home production and local consumption to market-oriented intensive agriculture, enabled by the improvement in transportation brought about by newly constructed roads, canals, and railroads. Farmers responded to the expanding markets by clearing more forested land and draining wetlands, often on marginally productive sites. Pasture remained the primary land use, with beef and wool the dominant farm products until canal and rail connections with the West

HARVARD FOREST ARCHIVES

Height of intensive farming, 1830. The percentage of land cleared for tillage, pasturage, orchards, and building sites in central Massachusetts was about 70 percent. A century later, the percentages of cleared and forested areas had been reversed. The stone walls testify to the tremendous labor required to farm land that is better adapted to growing trees than hay and grain.

and relaxation of wool tariffs in the 1830s and 1840s reduced their profitability.[22] Most farm families also engaged in home production of some sort (shoes, hats, clothes), and many earned some income from mills or tanneries. Local industry thrived, and most hill towns reached their peak levels of agricultural and commercial activity, as well as population, during this period.[19] However, this period also represented the start of the region's shift to industry, a factor that together with the expanding national transportation network and westward settlement initiated the decline of New England agriculture.

Many settlements literally moved downhill, changing from ridgetop agricultural villages to riverside industrial towns for a variety of reasons. Hill towns without significant waterpower resources were unable to participate in the transition from an agricultural to a manufacturing economy. The new factories for producing textiles, wooden products, and tools needed water to power their machines.[25] The developing railroad network, which followed the same watercourses that the factories used for power, transported raw materials and finished products to and from the factories. The new roads and railroads allowed many nonperishable farm products to be shipped from the Midwest more cheaply than they could be produced in Massachusetts.

Many factors contributed to the decline of Massachusetts agriculture, but depletion of the fertility of the land was not a major one. In fact, there is evidence that the quality of tilled land in hill towns improved through the eighteenth and nineteenth centuries.[26] The disadvantages of Massachusetts farmland included stony soil and small fields divided by numerous stone walls, which were incompatible with mechanization. Industrial production and improved transportation removed opportunities for supplemental income by reducing the need for local artisanship. Social factors also contributed to the decline of Massachusetts' hill-town agriculture: attractiveness of urban amenities and income, the decline of interest in agricultural life, and the shrinking economic opportunities in small towns.

The pattern of decline was strongly influenced by regional geography. Towns adjacent to developing industrial centers like Worcester and Fitchburg had a ready market for fuelwood, produce, and milk, while those more distant produced butter, cheese, and hay. The farthest distant towns declined most rapidly.[22,27] In 1810 Massachusetts was an agricultural state with a population of 412,000 that was remarkably evenly distributed in rural areas (79 percent), with the exception of Boston, Salem, and a few other coastal communities. Industrialization brought a tremendous increase and concentration of population in urban and, more recently, suburban centers. In 1975, 85 percent of the population of 5.8 million was located in urban areas. In contrast, many rural communities have greatly declined in population over the past hundred years.[28]

How did our forests fare during the agricultural period? By the late eighteenth century the gradual clearing of the first half of that century had become a rapid deforestation that continued until the mid-nineteenth century. Forest clearing was concentrated in the uplands, with the wetter swamps and steep, rocky slopes generally left as woodlots. The Berkshires were the last areas to be cleared and were never developed for agriculture to the extent that the remainder of the state was. The statewide peak in the level of deforestation was reached about 1860, by which time nearly 70 percent of the land was cleared. Many areas east of the Berkshires experienced the same pattern as Petersham and the Prospect Hill tract of Harvard Forest, with maximum clearance in the 1840s to 1860s, when less than 20 percent of the forest remained. The location and amount of forest left uncleared varied by geography. For example, in the north-central portion of Massachusetts from the Connecticut River valley to eastern Worcester County, the hills east of the valley, with many rocky ridges, remained largely forested, as did the north-south-trending, poorly drained valleys farther east. Most of the rest of the region was cleared.

Of course, even areas not cleared for agriculture were harvested intensively by the nineteenth century. The growing rural populations, whose numbers peaked in the mid-1800s, required large amounts of cordwood for fuel. Petersham, for example, had a population of nearly 1,800 people in 1840. Assuming an average household size of six, this population would


ASHBURNHAM
Forest
Meadow
Open
1830
1980
BARRE
Forest
Meadow
Open
1830
1980
DEERFIELD
Forest
Meadow
Open
Deerfield River
Connecticut River
1830
1980

have represented three hundred households to heat. If each household used 15 cords a year (a conservative figure when fireplaces are used), they would have required a total of 4,500 cords of fuelwood a year. The 20 percent of Petersham that remained forested in 1840 represented about 6,000 acres. Because Massachusetts forests can be expected to grow between one-half and one cord of hardwood per acre per year, virtually all the woodland growth in Petersham could have been used for fuelwood.

These hardwoods were probably managed by means of a coppice system, in which trees would be harvested very young (every twenty to forty years), left to resprout, and then harvested again as soon as the new growth was big enough to burn. Across upland Massachusetts most farms could maintain woodlots to satisfy their own fuel needs, but near cities and along the coast where settlements had been in place longer, the fuelwood was soon exhausted and had to be brought great distances by ship at considerable expense.

Although fuel was by far the dominant use of wood in the early 1800s, the remaining forests also faced other demands. Hemlock and chestnut trees, especially, were cut to provide tanbark for tanneries. Lumber was needed for constructing houses, barns, and public buildings. Wood was used to make charcoal, and fences had to be built. The scarcity of wood by the early 1800s probably accounts for many of the stone walls that still exist along boundaries and in pastures, where the stones would not have had to be removed for plowing or mowing; by then stones were more readily available than wood.

Postagricultural and Modern Periods

The decline of agriculture in the second half of the nineteenth century was accompanied by a corresponding regrowth of forest. Our present forests can be divided into secondary forest on land formerly cleared and used for agriculture (plowed or grazed), and primary forest on land never actually cleared but harvested throughout the agricultural period. As we have seen, the major portion of upland farmland was used for pasture, and even tilled land may have reverted to mowing or pasture before final abandonment. The resulting sod surface was not hospitable to many "pioneer" tree species such as birch and aspen, whose small, windblown seeds would often dry out and die after germinating; the sprouting seeds were trapped in the grass unable to reach mineral soil. The sod did, however, provide a suitable seedbed for the windblown but larger seeds of white pine, which colonized vast areas of abandoned farmland. Pines were much less likely to have been cut for fuelwood, and those left as shade trees in a pasture or along a fencerow could colonize many acres with dense stands of young pine. Moreover, animals still grazing these pastures would avoid pine seedlings while devouring most broadleaf species.

These new forests grew quickly, and by the late 1800s supported renewed harvesting for lumber and especially for shipping containers. The new portable steam sawmill, in common use by the turn of the century, permitted logging throughout the backwoods areas. Tremendous volumes of "old-field" (or abandoned-field) white pine were harvested, peaking in 1910–1911. During this timber boom, extensive harvesting of all species across the state resulted in large tracts of even-aged, young, low-value stands. Many of these cut-over stands, considered nearly worthless at the time, were acquired by the state for overdue taxes and have formed the basis of our state forest system. It was at this time, the early twentieth century, that the excesses of the timber industry throughout the East gave rise to the conservation movement, which was strongly represented in Massachusetts.

When the old-field pines were harvested, they were unable to sprout from the remaining stumps and roots (except for pitch pine, our only

Maps of three townships characteristic of different physiographic regions in central Massachusetts depicting distinctive amounts and patterns of forest, open land, and meadow in 1830 and 1980.

Ashburnham, on rocky hills near the New Hampshire border, was least extensively cleared and today is the most forested. Barre, on rolling terrain in the central uplands, was extensively cleared for agriculture but has largely reverted to forest. Deerfield, in the Connecticut River valley, was extensively cleared except for a few north-south bedrock ridges, and the fertile valley bottom remains in agriculture today.

HARVARD FOREST ARCHIVES

Agricultural abandonment and establishment of old-field white pine, 1850. Almost immediately the forest started to reclaim the idle fields and pastures. They were quickly seeded to white pine, with hardwoods such as red maple, white ash, red oak, chestnut, gray and paper birch forming a minor element.

First crop of old-field white pine harvested, 1910. From 1890 to 1920 portable sawmills appeared everywhere, and many new wood-using factories were established. With yields of 25 to 50 thousand board feet per acre and standing lumber valued at $10 per thousand, one might well envy a farmer who owned a 100-acre woodlot, worth perhaps $30,000—a wholly volunteer crop on which only taxes had been expended.

Old-field white pine is followed by hardwood, 1915. Five years after logging, hardwoods are primarily growing in the open lanes between the windrows of slash. These trees originated as stump sprouts—red maple, red and white oak, white ash, hard maple, chestnut, black cherry, black birch—or as seedlings of light-demanding species—gray and paper birch, pin cherry, and poplar.

Hardwood stand reaches cordwood size, 1930. Twenty years after logging on moderately moist soil, red maple, gray and black birch, and most other species begin to slow their growth upwards. Red oaks maintain a steady growth in height and girth so that by sixty years they will have formed an overstory above the other trees.

native conifer with this ability) and so had to reestablish themselves on the site from seed. As the old-field pines were growing, however, various broadleaf species, including oaks, red maple, and cherry usually established themselves beneath them from seeds carried in by animals or blown in by the wind. All these hardwoods have the ability to sprout from cut or damaged stems. Therefore, even if they were cut back when the pines were harvested, the hardwoods could grow much more quickly from their established root systems than could the tiny pine seedlings. This succession from a first generation of old-field white pine to a second generation of mixed hardwoods has been typical across most of Massachusetts.

The proliferation of old-field pine across Massachusetts in the second half of the nineteenth century, before they were harvested and replaced by hardwoods, led to problems as well as economic benefit. The vast expanses of young pines fed an epidemic of a native insect, the white pine weevil. The larvae of this insect eat the terminal buds of young pines, killing the leader and releasing the branches in the topmost whorl to replace it. At best, the growing trunks develop a crook; at worst, they divide into multiple, spindly stems. In either case the economic value of the trees is greatly reduced. White pine blister rust, a fungal disease lethal to white pine, also spread rapidly through the tracts of old-field pine. This disease requires an alternate host of the genus *Ribes* (currants and gooseberries) for part of its life cycle. During the 1930s the state and federal governments conducted a massive eradication program for *Ribes,* with men marching through the woods tens of feet apart pulling up wild *Ribes* plants. The prevalence of white pine weevil and blister rust also led in the 1920s and 1930s to red pine being planted across the state on many sites where white pine might normally have grown, because red pine is not affected by either pathogen. Although red pine is at the very southeastern edge of its range in western Massachusetts, these plantations have generally done well. Many are now maturing and being harvested.

The extensive old-field white pine stands also played a major role in the most dramatic natural disturbance to affect our forests in the twentieth century, the hurricane of September 21, 1938. Historically, hurricanes have been a major force in shaping Massachusetts forests. The 1938 storm followed a track similar to that of other historically significant storms (1788, 1815), but several factors conspired to make it the most destructive storm in our recorded history. The week before had been very wet, satu-

The Dexter Woodlot, situated just south of Petersham village. Before the hurricane of September 21, 1938, this was one of the most attractive white pine groves in the region.

rating the soils and predisposing trees to windthrow. The added rain from the storm produced massive property damage from flooding along rivers, compounding the wind damage. Large areas of central Massachusetts still supported stands of old-field pine on land abandoned in the late nineteenth century. Even pine stands as young as thirty years of age suffered severe damage if their sites were not protected topographically from the southeast winds. Hardwood stands on similar sites were not as susceptible to damage unless they were at least twice that age.[13] The prevalence of old-field pines set the stage for the unprecedented impact of the storm on our forests, nearly three billion board feet of timber blown down. We had unintentionally created about as vulnerable a landscape as possible. There is evidence that the storms of 1788 and 1815 may have been similar in intensity and path, but they encountered a landscape with much less forest and their impacts were quite different.

In 1938 the vast tracts of blown-down pine presented a problem: the threat of fire. Fires often follow other disturbances, especially in conifer stands where the resinous foliage and lack of new green sprouts contribute to flammability. With this in mind, and in an attempt to recover some of the value of the blown-down timber, a massive salvage operation was undertaken that recovered much of the windthrown timber. Logging crews were brought in from all over the Northeast, temporary camps were set up, and logs were salvaged and brought to the mills. Because the volume of logs far exceeded the capacity of all the available mills, logs were stored in every pond in the area. As long as the logs remained underwater, away from oxygen in the air, they were preserved. Many ponds in central Massachusetts were dammed and raised to their present levels in order to accommodate as much salvaged timber as possible. The tremendous volume of lumber produced by the hurricane salvage also drastically lowered lumber values. To stabilize the price, the federal government bought up the vast supply, stamping "U.S." at the end of each log. Mobilization for World War II finally made use of this vast lumber supply.

Humans have been unwitting accomplices in several other recent forest disturbances as well. Increased mobility of people and products has resulted in numerous forest pests and pathogens being introduced from abroad. In many instances these organisms pose special problems because native plants possess little resistance to the exotic pests. Several such "immigrants" have severely affected our forests,

E. G. STILLMAN ARCHIVES OF THE ARNOLD ARBORETUM

HARVARD FOREST ARCHIVES

Al Cline, director of Harvard Forest, 1939–1946, surveys white pine logs awaiting milling at Harvard Pond. Following the 1938 hurricane more than half of the fallen timber across New England was salvaged, purchased by the federal government, and stored in lakes and ponds to prevent insect damage, staining, and decay until the material could be milled. Today, occasional logs stamped on the end with "U.S." will be pulled from the mud bottom of a pond and, when dried, provide perfectly intact and usable wood.

and Massachusetts has the dubious distinction of being the introduction site of one pest that has damaged forests on a national scale. Gypsy moths were introduced into the United States in 1869, when Leopold Trouvelot imported them to Medford with the intention of using them as silkworms to develop a local silk industry. The moths quickly proved unsuited for this purpose and escaped into the local forests, where they found the native deciduous species, especially oaks and aspen, to be an ideal food source. Since then, gypsy moths have gradually expanded their range, and during periodic regional outbreaks consume virtually every

The Arnold Arboretum

SUMMER · NEWS · 1998

The Arboretum Reaches Out to Influence the World

Robert E. Cook, Director

Karen Madsen

Gary Koller shares his horticultural knowledge at an Arboretum Fall Plant Sale.

Whether it is our annual crop of interns, our visiting research fellows, or our experienced staff, the Arnold Arboretum serves as a training ground for career growth and achievement. As a result, this often leads to the loss of individuals to other institutions as they seek advancement in their careers. Such losses, though sad, are evidence of the strength of the Arboretum as a respected resource for knowledge and training in the fields of botany and horticulture. Over the past few years, the Arboretum has peppered its "alumni" throughout the country.

Two years ago Dr. Kim Tripp, who had been a Putnam fellow from 1994 to 1996, accepted the directorship of The Botanic Garden of Smith College in Northampton. Though she has taken on a new and challenging role, Kim retains a research appointment at the Arboretum.

In 1996, Richard Schulhof, director of public programs, was named director of Descanso Gardens in Los Angeles, after almost seven years at the Arboretum. Dr. Candace Julyan has been appointed to replace Richard in a re-organized education department. Before coming to the Arboretum in 1995 as project director for our Community Science Connection, Candace developed and directed the National Geographic Kid's Network. Though we miss him greatly, Richard continues to work with Candace by participating in the Community Science Connection.

After 17 years of service, Pat Willoughby, our superintendent of grounds, moved to a wonderful opportunity in the Boston suburbs, becoming superintendent of grounds at Wellesley College in 1997. His able assistant for six years, Julie Coop, has been appointed to his position at the Arboretum. Julie was in charge of maintenance at the Case Estates in Weston from 1988 to 1991. With Julie's promotion, we have hired a new assistant superintendent, Tom Akin, who comes from Weston Nurseries.

Chris Strand, who supervised visitor services for four years, announced his departure from the Arboretum in the fall of 1997. He has been appointed manager of Green Spring Gardens Park in Virginia. Ellen Bennett has recently assumed Chris' restructured and renamed position as manager of horticultural information. Prior to her position at the Arboretum, Ellen worked at the Massachusetts Horticultural Society for three years as director of education and as community outreach coordinator.

With the new year came three other critical changes in Arbore-

tum staff. Gary Koller, who had been our senior horticulturist for over twenty years, announced that he would retire in July to work full-time on a thriving landscape design business. Gary had been serving half-time at the Arboretum for the past five years while his business was growing, and in retirement he will retain an appointment as horticultural fellow and will continue to teach in our adult education program and write for *Arnoldia*.

Stephen Spongberg, who had been horticultural taxonomist with us for more than a quarter century, also retired to accept a wonderful opportunity as director of Polly Hill Arboretum on Martha's Vineyard, an entirely new institution that will be developing its collections and programs over the coming years under Steve's leadership. He, too, has retained a research appointment at the Arboretum, and we anticipate growing close relations with our sister institution on the Vineyard.

Finally, Professor Peter Stevens has announced that he will be leaving with his wife, Professor Toby Kellogg, a former Putnam fellow at the Arboretum, for the University of Missouri at St. Louis, where they will fill two tenured professorship positions. Peter is a world expert on the tropical flora of Southeast Asia, and his systematic knowledge and experience will be greatly missed.

In each of the above instances, our colleagues have moved to an exceptional opportunity for career development; these changes have given the Arboretum the chance to recruit new staff and rebuild programs. For instance, three job searches are currently underway, for a horticulturist, a botanical taxonomist, and a researcher experienced in the biology of tropical forests.

The Arnold Arboretum is a strong institution dedicated to education as well as research, and an important part of education involves shaping individuals for positions of leadership and responsibility. Though inevitably these positions will often be elsewhere, the Arboretum will continue to serve the fields of botany and horticulture in this important way. It is one more way we can influence the world.

1998 Interns

Karen Madsen

The interns of 1998: top row from left, Yong Chan Park, Kristin Berry, Bethany Grasso, Sandy Talcott, Nigel Gurnett, Marc Fortenberry, Loise Cretinon, Derrik Daly; bottom row from left, Fritz Bottger, Matthew Coyner, Angie Martin, Nicki Richardson, Gwen Newman, and the manager of the intern program, Assistant Superintendent Tom Akin. Missing was Lise Caron.

With members that represent our local region, the international community (France and Korea), and many states in between, the Arboretum's intern class of 1998 worked enthusiastically throughout spring and summer. They took classes taught by Arboretum staff on a variety of horticultural subjects, among them woody plant identification, integrated pest management (IPM), pests and diseases, and plant propagation. In addition to working on an erosion abatement project, the interns were involved with numerous maintenance and renovation projects throughout the grounds. To supplement their experiences at the Arboretum, interns participated in several educational outings, including trips to the New York Botanical Garden, Mount Auburn Cemetery, and the new Polly Hill Arboretum on Martha's Vineyard. The interns' diligence and enthusiasm made a valuable contribution to the Arboretum that is apparent at every turn.

Frances Maguire Named Harvard Hero

On June 10, all the Harvard Heroes were recognized in a ceremony in Sanders Theater, Memorial Hall. Harvard president Neil Rudenstine and his senior staff from central administration were in attendance to express their appreciation of the Harvard Heroes.

In June, Sally Zeckhauser, Harvard University's vice president for administration, announced this year's Harvard Heroes—employees in Ms. Zeckhauser's unit whose job performance has been outstanding. Frances Maguire, director of finance and administration, has been named the Arnold Arboretum's 1998 Harvard Hero. Director Bob Cook noted that Frances has done a superb job in managing the financial affairs of the institution, saving many thousands of dollars over the past decade due to her careful consideration of income and expenditures. Her deep knowledge of the difficult Harvard accounting system has been invaluable to the Arboretum. Recently, Frances has taken responsibility for helping the Arboretum's transition to a completely revamped accounting system being adopted by Harvard University. For these and numerous other reasons, Frances deserves great recognition and thanks from the Arboretum and from Harvard.

Fundraising Reaches New Heights

Lisa Hastings
Director of Development

The Arnold Arboretum completed a record-breaking year with respect to the Campaign for the Arboretum. Total gifts and commitments for the fiscal year ending June 30, 1998, reached $2,016,834, the largest amount raised from philanthropy in the Arboretum's history. The total represents an increase of 191 percent over the $692,111 raised in fiscal year 1997.

MAJOR GIFTS: New records were established both in total dollars raised and total number of donors. Gifts over $10,000 reached a total of $1,704,373, an unprecedented number that includes the Arboretum's first million-dollar gift. The number of donors of more than $10,000 increased 170 percent, from 10 in 1997 to 27 in 1998. Overall, the Arboretum

• *continued on page 4*

1997 Intern Is 1998 Apprentice

Tom Por joined the Arboretum staff in April as apprentice in the living collections department, only the second person to hold this relatively new position. Originally from St. Thomas, Ontario, he comes to the Arboretum after graduating from the Niagara Parks Commission Botanical Gardens and School of Horticulture. Tom also has received a bachelor of arts degree in history with honors from the University of Toronto. The Arboretum is not an entirely new entity for Tom, as he served as an Arboretum intern in 1997. As a member of the living collections department, he will be responsible for a variety of projects on the grounds, including erosion abatement on the esker just off Meadow Road. During his year at the Arboretum, he will circulate through all the units within living collections, thus acquiring deeper knowledge of the maintenance requirements of a scientific collection of woody plants.

Karen Madsen

• from page 3

received 85 gifts over $1,000, an increase of 255 percent over the 22 gifts of this size received in fiscal year 1993, the first year of the campaign.

MEMBERSHIP/ANNUAL APPEAL: A total of 638 new members joined the Friends of the Arnold Arboretum last year, bringing the total number of members at year's end to 3,364. New members, coupled with a renewal rate of 80 percent and a healthy increase in membership upgrades, resulted in an increase of nearly 20 percent in membership and 23 percent in membership income. The largest membership increases (40 percent) came at the level of Sustaining Member ($100) and above, a testament to increased outreach and the active participation of new and reinvigorated volunteer leadership. In addition, funds donated through the Annual Appeal raised $89,011 from 271 donors, a 29 percent increase in dollars and a 27 percent increase in the number of donors over the previous year.

THE WOMEN'S MATCHING FUND: The Women's Matching Fund offered through Harvard University has had a swift and positive impact on our fundraising. Due to gifts and pledges made by nine women, the Arboretum has qualified for $391,000 since the fund was announced. To date, $10 million of the total fund balance of $15 million is committed across the university; the opportunity to qualify for matched funds will end when the fund balance is depleted.

SUMMARY: Total gifts and pledges in the Campaign for the Arboretum stand at $5,596,243, representing 68 percent of the Arboretum's $8.2 million goal. With less than 18 months left before the conclusion of the university-wide campaign, the coming year will be critical to closing the gap and successfully completing the Arboretum's campaign.

New Staff

Karen Madsen

In July, Ellen Bennett started as manager of horticultural information at the Arboretum. Ellen comes from the Massachusetts Horticultural Society, where she served as director of education and as community outreach coordinator. Originally from Virginia, she earned her master of science degree in public horticulture administration through the Longwood Graduate Program at the University of Delaware. As a member of the education department, Ellen will create a new docent program and work on a variety of issues related to the public face of the Arboretum. She will also spend a portion of her time working with the living collections department.

Laurie Chidester has started work as curriculum and web specialist in the education department. Laurie spent last year as a student in the Harvard Graduate School of Education working on her master of education degree, focusing on technology in education. Earlier, during 13 years in software development, Laurie made use of her master's degree in computer systems engineering. Originally from the Baltimore area of Maryland,

Karen Madsen

Laurie will be focusing on the Community Science Connection project funded by the National Science Foundation. She will use the internet to support teachers and students in an inquiry-based curriculum model in the study of trees.

Karen O'Connell, membership coordinator, joined the Arboretum development staff in July, replacing Kelly Harvey who left the

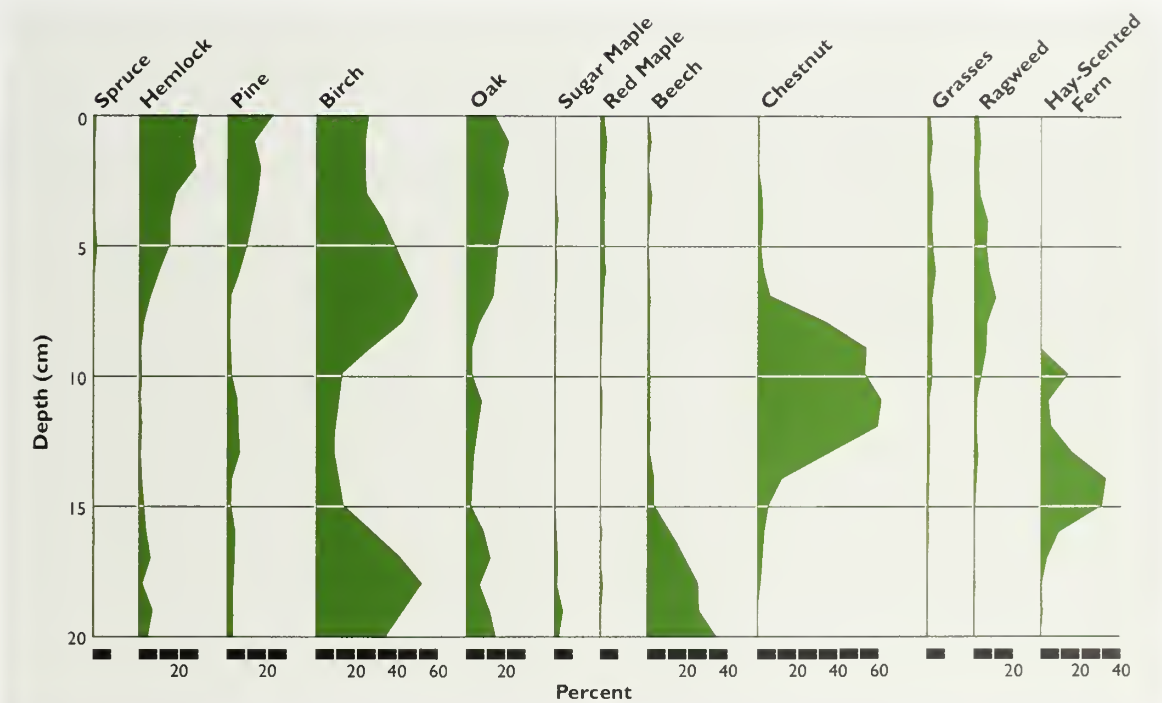
Karen Madsen

Arboretum to begin graduate studies in veterinary science. Karen brings a wealth of experience in data management. She worked for two years as data manager in the marketing and development department of the Boston Ballet, prior to which she spent four years with the Environmental Defense Fund serving as office manager and records manager. A 1989 graduate of Boston College with a degree in marketing, she will oversee member services and is looking forward to meeting the Arboretum's growing constituency.

green leaf in the forest, leaving it in mid-July looking nearly as barren as in midwinter. Defoliation for two successive years is especially harmful. The outbreak of 1980–1981 across the Northeast was particularly severe, causing extensive oak mortality. Today the gypsy moth has spread throughout the Northeast and into the Middle Atlantic and midwestern states and is one of the most destructive forest pests throughout the region.

Probably the most dramatic effect on our forests by an introduced pathogen has been that produced by the chestnut blight fungus. Although the details of its introduction are not certain, the fungus was first noticed in New York in 1904 and rapidly spread throughout the range of the American chestnut, passing through Massachusetts in 1913–1914. An especially virulent pathogen, chestnut blight fungus is the only pest that has effectively eliminated mature individuals of its host, greatly altering our forests in the process. Chestnut was certainly one of the most useful trees in the nineteenth-century forests, providing abundant crops of edible nuts, bark for tanning, and excellent wood that was beautiful, decay-resistant, and as strong as oak but lighter. It also sprouted vigorously and grew very quickly and therefore increased in numbers in areas that were repeatedly harvested.

By the early 1920s all the large chestnuts in the state had been killed. However, because in



Pollen diagram from the humus soil in a hemlock forest at the Harvard Forest, Petersham, Massachusetts. The site is a primary forest that was never cleared for agriculture but was clear-cut early in the settlement period (apparent in the pollen diagram at a depth of approximately 17 centimeters) and then cut repeatedly for firewood.

Each tree species responded differently to the series of human impacts. Chestnut benefitted greatly from the cutting activity until its virtual elimination by blight in 1913 (seen at about 8 centimeters in depth). Other major changes are the decline in several long-lived, shade-tolerant species during the agricultural period. Both hemlock and beech are very sensitive to fire and could be largely eliminated from upland areas by repeated fires, a rather common agricultural practice. Beech and sugar maple never recovered to presettlement levels of abundance and have been replaced by oak, pine, and red maple, which have gradually increased: hemlock has become the dominant species on this moist lowland following the loss of chestnut to the blight. [29]

HARVARD FOREST ARCHIVES

Farm abandonment accidentally provided more favorable conditions for wildlife than did old forest: low-growing game food and cover are much more plentiful and varied. Shrubs and apple trees furnish fruit and browse; valuable herbaceous species and a wealth of insects are within reach of young birds. Deer, rabbits, woodcock, and aquatic birds are among the wildlife that flourish in old fields, abandoned millponds, and stone walls.

effect the fungus kills by girdling the trees—gaining access through cracks in the bark and preventing transport of water and nutrients past the point of infection—the roots and base are not affected and can send out new sprouts. The chestnut's decay resistance, especially within the sapwood, has preserved many stumps that testify to the former importance of this species, and today chestnut sprouts are common in our woods. Individual stems are usually killed by the time they are several inches in diameter, when the bark naturally develops cracks, only to be replaced by new sprouts. Chestnut's place in the forest has been taken by a mixture of species, especially oaks, but its wood and its nuts cannot be replaced.

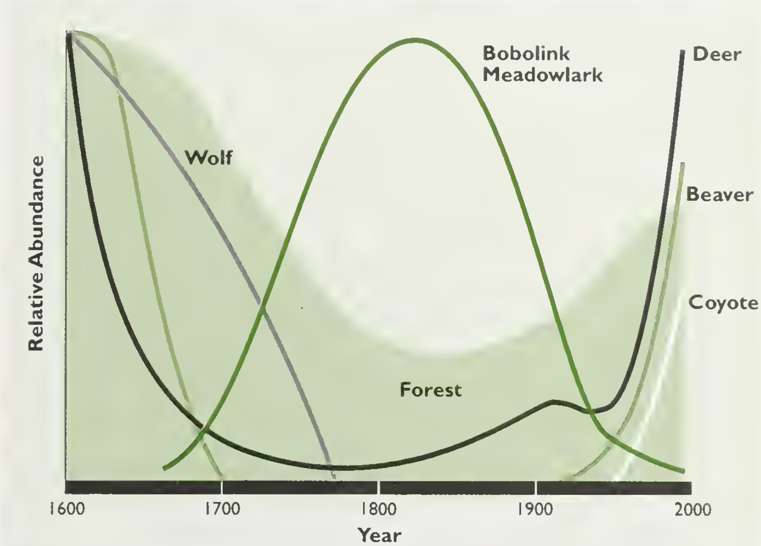
Other native tree species have also been significantly affected by human-introduced agents, although none so dramatically as the chestnut. Dutch elm disease, a wilt fungus transported by a bark beetle, completely transformed the appearance of almost every town in the state in the 1950s and 1960s by killing the stately shade trees that lined most of our main streets. The disease is passed from tree to tree by insects above ground and through root grafts below ground in areas where the trees grow adjacent to each other, as in street plantings. Its effects were somewhat less traumatic in our forests, because elm occurred in mixed stands and exhibited a greater range of natural resistance than did chestnut. Nevertheless, the devastation of the elms in our urban landscapes once again demonstrates the susceptibility of manmade monocultures to various pathogens.

More recently, many of our beeches have been killed or disfigured by beech-bark disease. This disease, caused by the coincident impact of a fungus and a scale insect working together, is steadily spreading southward after being introduced into the Canadian Maritimes. Hemlock woolly adelgid is beginning to cause mortality in the southern Connecticut River valley area and has been reported in many other areas of

the state as it slowly advances north. This aphidlike insect, first introduced to the West Coast and then to Maryland on nursery stock from Japan, poses a dire threat to hemlock forests because hemlocks have shown little resistance to its effects and are incapable of sprouting. Moreover, because many hemlock stands occupy steep habitats and produce deep shade, thereby creating unique microenvironments, their loss would represent drastic changes to many of our forests.

Over the past several decades, however, it is through logging and land conversion for suburban development that humans have most affected our forests directly. The regrowth that followed the cutting of old-field pine stands and other forests early in this century and the 1938 hurricane has produced an abundant middle-aged and maturing forest, much of which has been and is being harvested at varying degrees of intensity. Limitations set for environmental reasons on harvesting federally owned trees together with a strong export market have resulted in added pressures on Massachusetts' forests. Despite these pressures, however, the average size of our trees has been steadily increasing. In some instances we have even managed to reduce the impact of suburban development on the forest. Significant numbers of people are now building homes on large forested lots, clearing only the area immediately around the houses, and in some developments buildings are clustered together, reserving the majority of land as forest or open space. While both of these development patterns alter the forest, they are much less destructive than traditional tract development.

Wildlife species in Massachusetts have been significantly influenced by human-induced changes in the landscape as well as by hunting. Information on this subject is difficult to gather and much of it is indirect. It is believed, however, that most members of the large, broad-ranging species, including elk, wolf, mountain lion, and moose, were eliminated during the initial period of forest clearance. Deer were nearly eliminated by the mid-1800s. Because they represent an edge species, however—using open areas for browsing and forests for cover—and are tolerant of human activities, deer have responded so favorably to the return of the forest that they have reached densities detrimental to the vegetation in those areas where they are not controlled by hunting.[31] Beavers were extirpated by the 1700s owing to the value of their pelts. They were successfully reintroduced in West Stockbridge in 1928 and have subsequently expanded their range to the point of overutilizing existing habitat. More recently, wild turkeys have been reintroduced very successfully, and moose are returning on their own as part of their growing northern populations migrate south. These three species are responding to the expansion of our woodland area, as have the black bear and the fisher, which have significantly expanded their ranges and numbers within the past seventy-five years. Other species, most notably open-land birds such as the bobwhite and meadowlark, have decreased in number as the forest has regrown and matured.



Changes in the relative abundance of selected animal species in Massachusetts over the past 400 years. Whereas the wolf has been eliminated and remains absent, beaver have been reintroduced and the coyote represents a new species in the landscape.[30]

IV. Present Conditions and Future Prospects

How do the forests we see today differ from the forests the colonists found? The process of deforestation and reforestation has produced landscape patterns that vary with the distribution of natural and cultural features within local areas. Today, open agricultural land is primarily found only in broad river valleys and on the crests of broad ridges. Urban concentrations developed first along the coast and major rivers and later along the railroads, which tended to follow the rivers. More recently, suburban development has occurred along major highways, especially near junctions. Forests now predominate outside these zones, and in protected reserves and some of the wetlands within them, and are under the greatest pressure at the edges of these zones.

PETER DEL TREDICI

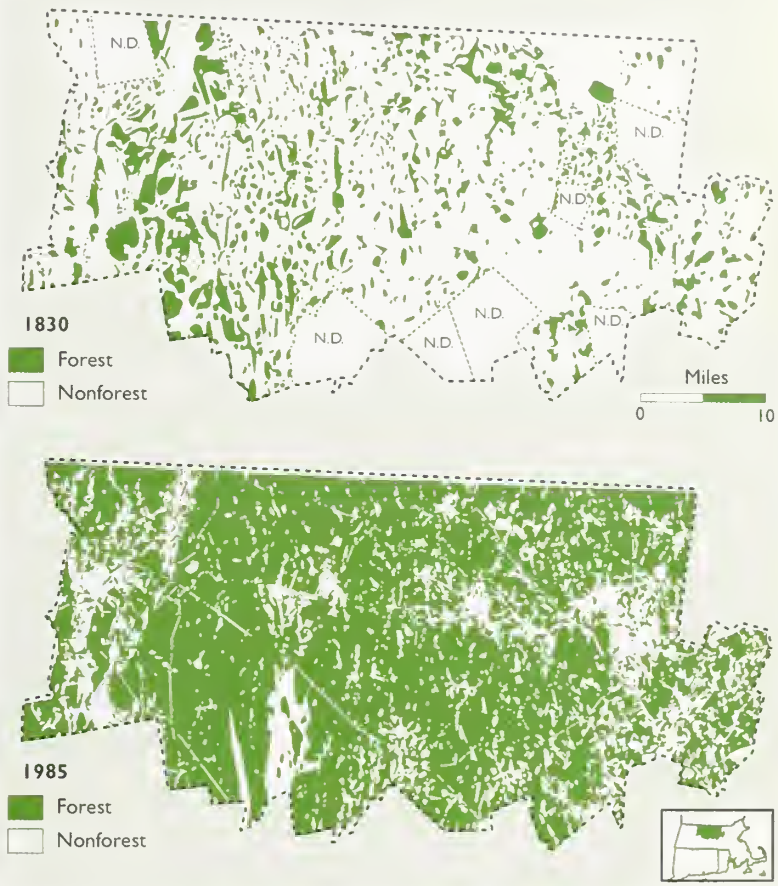
Old stone walls surrounded by forest bear witness to abandoned farmland.

The changes have strongly favored a new landscape of even-aged forests, with sharp boundaries between types. Agricultural clearing and abandonment, heavy cutting for fuelwood, intensive harvesting of old-field pine and other species early in this century, the hurricane of 1938 with its subsequent salvage harvesting—all these phenomena have combined to create the even-aged forests we find throughout Massachusetts. Land-use regulations and land ownership boundaries create visible differences in vegetation that tend to be perpetuated through time and through changes in ownership. Trends in the size of fields and farms and in regional timber harvesting practices have imposed a repetitive patchwork of forest types that has replaced the natural vegetation patterns. These even-aged forests and imposed patterns increase the possibility that disturbances will in the future cause far more damage than might be expected in a more diverse forest. Moreover, the relative scarcity of very young forests inhibits the growth of species that require this type of habitat.

Although they tend to be even-aged, over the past one hundred-plus years, the forests in Petersham have continually increased in area and size, a trend that has been repeated in forests throughout the state. How has the composition of our forests been affected? The most dramatic change has been the increase in white pine following agricultural clearing and subsequent abandonment. Prior to European settlement white pine was confined mainly to sandy outwash soils that had undergone natural disturbance or to sites heavily burned by Indians; or it appeared as scattered, emergent individuals

in old stands of mixed species. Following agricultural abandonment, especially of pastures, white pine proliferated throughout most of the state on sites it would never have occupied without prior clearing and grazing. Despite intensive harvesting and the 1938 hurricane, white pine remains much more dominant and widely distributed today than it was before European settlement.

On woodlots, repeated cutting for fuelwood and burning for agriculture in the nineteenth century favored an increase in invasive, shade-intolerant pioneer species—gray and paper birch, aspen, pin and black cherry—as well as species that sprout prolifically—chestnut, oak, red maple, hickory, and birch. Chestnut is probably the species that responded most favorably to these nineteenth-century disturbances because it sprouts prolifically from dormant basal buds and is capable of phenomenal rates of growth both in height and diameter when reproducing vegetatively.[32,33]



Forest cover (shown in green) for north-central Massachusetts in 1830, at the approximate peak of agricultural clearance, and in 1980. Major physiographic regions include the Connecticut River valley, the rough Pelham Hills to its east, and the undulating central upland regions farther east. ND indicates no data.[34]

As our forests have reappeared following the period of extensive cutting at the turn of the century, the loss of chestnut in the teens, the 1938 hurricane, and the more recent initiation of fire-suppression policies, long-lived, shade-tolerant species have gradually increased in number—hemlock, sugar maple, and, to a lesser extent, the highly disturbance-intolerant beech. However, early survey records and pollen analyses suggest that these species, especially beech, remain well below their presettlement distributions. On the other hand, oak, which requires at least moderate disturbance for successful regeneration, may be more common than before settlement.

Significant new harvesting has followed on the recent maturation of considerable areas of Massachusetts forest. At the same time, the environmental awareness that began to develop in the 1960s has led to new regulations on forest-cutting practices;[35] these in turn have raised the extent and quality of professional forest management across the state. The growing understanding that forests do not function in isolation has highlighted the need for regionally mapped information for use in designing management practices within the context of a region or ecosystem. Fortunately, the requirement to file a cutting plan for all harvests greater than 25,000 board feet has made it possible to map current harvesting patterns in much finer detail than was possible in the past.

The Pisgah old-growth tract in Westminster, New Hampshire. This forest of 300-year-old white pine, hemlock, and hardwoods was purchased by the Harvard Forest in 1922 in order to protect it from logging and to provide a study area for investigating natural forest processes. In the hurricane of September 22, 1938, it was completely blown down, and the area has formed an important long-term study in forest dynamics and recovery from disturbance.

Growing environmental interest has also led to the discovery of remnant patches of old-growth forest, once assumed to have been entirely eliminated by the extensive clearing and harvesting of the nineteenth and early twentieth centuries. Although exact definitions of "old-growth" vary considerably, these remnants typically include dominant trees well over two hundred years old and show minimal evidence of human disturbance. At present between 500 and 1,000 acres of old-growth forest are recognized in Massachusetts,[36] and the number continues to rise as more areas are investigated by scientists with a better understanding of what they are looking for, which is not necessarily huge old trees.

Many of these remnants are small patches of barely ten acres—which, according to one current working definition, is the minimum size necessary to prevent significant edge impacts—but some remnants are considerably larger. Most are located on steep, rocky slopes, often on headwater streams, where they were inaccessible for harvesting from either the stream valley or the broad ridges and were somewhat protected from natural disturbances as well.

Not even these sites offer protection from recent human disturbances, which are subtle but pervasive. These include atmospheric pollution and rising carbon dioxide (CO_2) levels, both of which may be implicated in the global warming predicted by many scientists. While neither of these forces has yet had serious, measurable impacts on our forests, both have the potential to significantly alter them in the future.

Because the effects of pollutants are extremely complex, the eventual impact of long-term exposure is still largely unknown.

Map of currently known old-growth stands in Massachusetts.

The amount of nitrogen (NO_x)—an important component of atmospheric pollution—increases as one moves farther west and to higher elevations in Massachusetts.[37] As the major limiting nutrient for plant growth in our soils, nitrogen works initially as a fertilizer, but at higher concentrations it may lead to nutrient loss through leaching.[38] Ozone found at low atmospheric elevations is another pollutant with potentially serious forest impacts.

Elevated CO_2 levels affect the quality of organic matter in the soil through their influence on plant growth, competitive interactions, and leaf chemistry, and have the potential to change global climate. We do not yet understand how forest communities and ecosystem processes might ultimately be changed by elevated CO_2 levels, nor do we know the local effects of global warming. Massachusetts' forests do have some impact on the global CO_2 level: because they are still relatively young and growing, our forests take up and store significant amounts of CO_2, slightly offsetting the increases from fossil-fuel burning and deforestation. CO_2 levels and pollution are both international issues that will require unprecedented levels of cooperation if they are to be controlled.

Our forests have changed constantly throughout geologic and historical time, but human-induced changes over the past three hundred years have been much more frequent, varied, and far-reaching. These changes have been superimposed upon natural disturbances, and where the two processes have acted in concert, as in the 1938 hurricane, the impact has been substantial.

The forests across the state today are quite different from those the colonists and Indians saw—indeed, they are quite different from those of sixty years ago. They will continue to change, but recent trends in carbon storage and increasing volume of wood will undoubtedly continue. Changing ownership patterns will increasingly affect forest development. Over the past fifty years both the term of ownership and the average size of forest properties have continued to shrink as our population has become less and

JOHN O'KEEFE

The tower of the Harvard Forest's Environmental Measurement Station measures exchanges of gases, energy, and moisture between the atmosphere and the forest. These measurements document the surprisingly high rate of carbon uptake by temperate forests that are recovering from earlier land use. It also documents seasonal changes in forest activity due to meteorological changes and ozone stress.

less agrarian and more and more mobile, and—as suburbs encroach on rural areas—as more and more people have built their homes in wooded areas. These trends will influence our forests and their management into the next century. At the same time, demands for forest conservation and preservation will no doubt increase—especially on public lands—as the value of our forests for recreation, amenity, and watershed-protection increases even more rapidly than their value for development or other economic uses. Humans—directly, indirectly, and in conjunction with natural processes—will continue to be the dominant force acting on our forests.

The recovery of Massachusetts' forests is testimony to the resilience of our landscape in the face of centuries of natural disturbance and unthinking human activity. However, it is critical that decisions regarding conservation, forestry, wildlife management—in fact, *all* environmental decision-making—begin with knowledge and an appreciation of the history and dynamic nature of our landscape. Without these, any plan will almost certainly produce surprises, if not failure. The forests have reclaimed abandoned farmland and now cover nearly two-thirds of Massachusetts. As our population expands onto this land, the new suburban forest owners, largely unaware of the history of our forests and only slightly more informed about changes now occurring, must become more knowledgeable about the dynamic nature of their backyard forests. We are blessed with a landscape and a climate that are ideally suited for growing trees and forests, but without an understanding of the past we may unwittingly lose many of the values these forests can provide.

Endnotes

[1] A. N. Strahler, *A Geologist's View of Cape Cod* (Garden City, NY: Natural History Press, 1966).

[2] M. B. Davis, Three pollen diagrams from central Massachusetts. *American Journal of Science* (1958) 256: 540–570.

[3] W. A. Patterson and A. E. Backman, Fire and disease history of forests. In *Vegetation History*, ed. B. Huntley and T. Webb (Dordrecht: Kluwer, 1988), 603–632.

[4] D. R. Foster and T. M. Zebryk, Long-term vegetation dynamics and disturbance history of a *Tsuga*-dominated forest in central New England. *Ecology* (1993) 74: 982–998.

[5] J. K. Wright, Regions and landscapes of New England. In *New England's Prospect: 1933* (New York: American Geographical Society, 1933), 14–49.

[6] N. Jorgensen, *A Guide to New England's Landscape* (Chester, CT: Globe Pequot Press, 1977).

[7] M. V. Westveld, Natural forest vegetation zones of New England. *Journal of Forestry* (1956) 54: 332–338.

[8] E. P. Stephens, The historical-developmental method of determining forest trends. Ph.D. thesis (Cambridge: Harvard University, 1955).

[9] W. H. Lyford and D. W. MacLean, Mound and pit relief in relation to soil disturbance and tree distribution in New Brunswick, Canada. *Harvard Forest Paper* (1966) 15.

[10] J. Jenkins, Notes on the Adirondack blowdown of July 15, 1995: Scientific background, observation, responses and policy issues, Wildlife Conservation Society Draft Report, 1995.

[11] D. R. Foster and E. R. Boose, Patterns of forest damage resulting from catastrophic wind in central New England, U.S.A. *Journal of Ecology* (1992) 80: 79–98.

[12] T. D. Allison, R. E. Moeller, and M. B. Davis, Pollen in laminated sediments provides evidence for a mid-Holocene forest pathogen outbreak. *Ecology* (1986) 67: 1101–1105.

[13] W. A. Patterson and K. E. Sassaman, Indian fires in the prehistory of New England. In *Holocene Human Ecology in Northeastern North America*, ed. G. P. Nicholas (New York: Plenum Publishing, 1988), 107–135.

[14] D. M. Smith, Storm damage in New England forests. M.S. thesis (New Haven, CT: Yale University, 1946).

[15] D. R. Foster, Species and stand response to catastrophic wind in central New England, U.S.A. *Journal of Ecology* (1988) 6: 135–151.

[16] G. C. Whitney, *From Coastal Wilderness to Fruited Plain: A History of Environmental Change in Temperate North America from 1500 to the Present* (Cambridge, UK: Cambridge University Press, 1994).

[17] W. Cronon, *Changes in the Land: Indians, Colonists and the Ecology of New England* (New York: Hill and Wang).

[18] C. Clark, *The Eastern Frontier: The Settlement of Northern New England 1610–1763* (New York: Knopf, 1983).

[19] D. R. Foster, Land-use history and four hundred years of vegetation change in New England, U.S.A. In *Global Land Use Change: A Perspective from the Columbian Encounter*, ed. B. L. Turner et al. SCOPE Publication (Madrid: Consejo Superior de Investifaciones Cientificas, 1995), 253–321.

[20] Information is derived from the following sources: For Massachusetts, D. R. Dickson and C. L. McAfee, *Forest Statistics for Massachusetts, 1972 and 1985*, Resource Bulletin NE-106 (USDA Forest Service, 1988); W. P. MacConnell, Remote sensing 20 years of change in Massachusetts, Massachusetts Agricultural Experiment Station Bulletin 630 (1975); F. W. Rane, *Fourth Annual Report of the State Forester of Massachusetts for the Year 1907* (Boston: Wright and Potter, 1908); and H. I. Baldwin, *Forestry in New England* (Boston: National Resources Planning Board Publication 70, 1942).

For Petersham, H. M. Raup and R. E. Carlson, The history of land-use in the Harvard Forest, *Harvard Forest Bulletin* (1941) 20: 1–64; W. P. MacConnell and W. Niedzwiedz, Remote sensing 20 years of change in Worcester County, Massachusetts, 1951–1971 (Amherst, MA: Massachusetts Agricultural Experiment Station, University Massachusetts, 1974); H. O. Cook, *The Forests of Worcester County. The Results of a Forest Survey of the Fifty-Nine Towns in the County and a Study of Their Lumber Industry* (Boston: State Printing Office, 1917); and Rane, *Fourth Annual Report of the State Forester.*

For Prospect Hill, D. R. Foster, Land-use history (1730–1990) and vegetation dynamics in central New England, U.S.A., *Journal of Ecology* (1992) 80: 753–772; and S. H. Spurr, Stand composition in the Harvard Forest as influenced by site and forest management, Ph.D. thesis (New Haven, CT: Yale University, 1950).

[21] Maps are compiled from the atlas of Worcester County (1830, unpublished) and analysis of aerial photographs for 1985.

[22] M. R. Pabst, Agricultural trends in the Connecticut valley region of Massachusetts, 1800-1900. *Smith College Studies in History* (1941) 26: 1–135.

[23] A. H. Baker and H. V. Izard, *Production Changes and Marketing Strategies of Worcester County Farmers, 1780–1865: A Case Study of the Wards of Shrewsbury* (Dublin, NH: Society for History of Early American Republic, 1987).

[24] C. Merchant, *Ecological Revolutions. Nature, gender and science in New England* (Chapel Hill: University of North Carolina, 1989).

[25] A. K. Botts, Northbridge, Massachusetts, A Town That Moved Down Hill, *Journal of Geography* (1934) 33: 249–260.

[26] N. Jones, An ecological history of agricultural land-use in two Massachusetts towns. Senior thesis (Amherst, MA: Hampshire College, 1991).

[27] A. H. Baker and H. I. Patterson, Farmers' adaptations to markets in early nineteenth-century Massachusetts. *Proceedings of the Dublin Seminar* (London: Antiquities Society, 1986), 95–108.

[28] Data from U.S. Census with maps modified from R. W. Wilkie and J. Tager, *Historical Atlas of Massachusetts* (Amherst: University of Massachusetts Press, 1991).

[29] D. R. Foster, T. M. Zebryk, P. K. Schoonmaker, and A. Lezberg, Post-settlement history of human land-use history and vegetation dynamics of a hemlock *(Tsuga)* woodlot in central New England. *Journal of Ecology* (1992) 80: 773–786.

[30] Modified from W. E. Bickford and U. J. Dyman, *An Atlas of Massachusetts River Systems: Environmental Designs for the Future.* (Amherst: University of Massachusetts Press, 1990).

[31] T. Kyker-Snowman, *1989 Quabbin forest regeneration study* (Boston: Metropolitan District Commission (MDC) Publication, 1989).

[32] R. Zon, Chestnut in southern Maryland, U.S.D.A. *Bureau of Forestry Bulletin* 53 (1904).

[33] F. L. Paillet and P. A. Rutter, Replacement of native oak and hickory tree species by the introduced American chestnut *(Castanea dentata)* in southwestern Wisconsin. *Canadian Journal of Botany* (1989) 7: 3457–3469.

[34] D. R. Foster, G. Motzkin, and B. Slater, Land-use history as long-term broad-scale disturbance: regional forest dynamics in central New England. *Ecosystems* (1998) 1: 96–119.

[35] Massachusetts General Laws, chapter 132, sections 40–46.

[36] P. W. Dunwiddie and R. T. Leverett, Survey of Old-Growth Forest in Massachusetts. *Rhodora* (1996) 98: 419–444.

[37] S. G. McNulty, J. D. Aber, T. M. McLellan, and S. M. Katt, Nitrogen cycling in high elevation forests of the northeastern U.S. in relation to nitrogen deposition. *Ambio* (1990) 9: 38–40.

[38] J. D. Aber, K. J. Nadelhoffer, P. Steudler, and J. M. Melillo, Nitrogen saturation in northern forest ecosystems. *BioScience* (1989) 9: 376–386.

The authors are ecologists on the staff of the Harvard Forest, a research and educational department of Harvard University located in Petersham, Massachusetts. David Foster is director of the Harvard Forest and teaches forest ecology and conservation in the Department of Organismic and Evolutionary Biology and the Kennedy School of Government. John O'Keefe is coordinator of the Fisher Museum, a small museum devoted to the land-use history, ecology, and management of New England's forests.

This article is adapted from "An Ecological History of Massachusetts Forests," in *Stepping Back to Look Forward: A History of the Massachusetts Forest,* edited by Charles H. W. Foster, published in 1998 by the Harvard Forest, and distributed by the Harvard University Press. The book can also be obtained postpaid from Harvard Forest, Petersham, MA 01366, where proceeds from the $28 price go to support undergraduate research and education in forest ecology.

Old-growth forest in New England before the hurricane of 1938.

How Land Use Determines Vegetation: Evidence from a New England Sand Plain

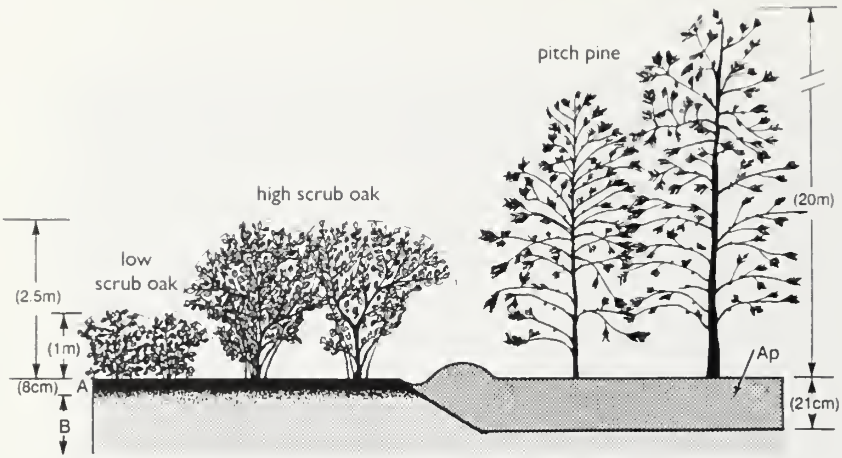
Glenn Motzkin and David R. Foster

Human activity exerts long-lasting impacts on natural ecosystems, and because today's forest composition reflects past land uses as well as natural phenomena, knowledge of land-use history and an understanding of its effects are integral to ecological study and critical for conservation planning. However, attempts to determine the relative contribution of land use vs. physical factors in controlling vegetation patterns have consistently been confounded by the strong correlation between past land use and original site conditions.

To evaluate the effects of historical land use, researchers at the Harvard Forest studied pitch pine-scrub oak communities on a broad sand plain in the Connecticut River valley of Massachusetts, a site that is unusually homogenous in topography, drainage, and soil texture. Such homogeneity enabled the researchers to detect the effects of differing land-use on the structure and composition of the vegetation. Also motivating the study was the rarity of pitch pine-scrub oak communities. They support several rare plant and animal species but have been substantially degraded by industrial, commercial, and residential development, and are therefore priorities for conservation throughout the Northeast.

The paleoecological record of the study area—1,900 acres on a flat outwash delta composed primarily of sand and gravel—suggests that pre-European fires were common, some of them, perhaps, ignited by a large regional Indian population. Like other sand plains in the region, the area was used for wood products from the eighteenth to the mid-nineteenth century. In the early nineteenth century, the Reverend Timothy Dwight, author of *Travels in New England and New York* (1821), described the Montague Plain and surrounding areas as "an extensive yellow pine plain covered with a lean, miserable soil." Nonetheless, 82 percent of it was subsequently plowed for crops before being abandoned in the early twentieth century. Agriculture had a major impact on vegetation but a relatively minor long-term effect on physical and chemical soil properties on this site. For instance, although visually striking, the difference between plowed and unplowed soil horizons is primarily one of color, the result of organic matter being redistributed within the soil by plowing.

Agricultural fields on Montague Plain were abandoned and allowed to reforest at least fifty years ago—some more than one hundred years ago—and yet the plant composition remains very different on areas that were once plowed compared to those that were never plowed. Some species are just as common today on formerly plowed areas as on unplowed sites. However, several species, most notably pitch pine *(Pinus rigida)* and gray birch *(Betula populifolia)*, are much more common on plowed sites. Of particular interest is a group of species that is characteristic of sand plain habitats and is common on unplowed portions of Montague Plain, but that has not successfully re-colonized former agricultural lands even though they were abandoned more than half a century ago. This group includes some familiar species, such as black huckleberry *(Gaylussacia baccata)*, wintergreen *(Gaultheria procumbens)*, blueberries *(Vaccinium* spp.*)*. Intensive soil and population analyses suggest that the failure of these species to re-colonize these sites does not result from plowing; instead, it appears that successful sexual reproduction is rather infrequent in these species. Their rates of vegetative spread are so slow that even one hundred years is not long enough for re-colonization.



Cross-sectional diagram across the major land-use, vegetation, and soils boundary at the Montague sand plain. An unplowed site is on the left, a plowed site on the right. Even after a century of forest growth, the soils on plowed sites exhibit a deep and light-colored A horizon, sharply separated from the underlying B horizon.

Fire has been important on the Montague Plain: high charcoal-to-pollen ratios in the paleoecological record, documentation of many large fires during this century, and field evidence of fire in 83 percent of the research plots testify to that. However, fire does not appear to be the primary determinant of vegetation patterns on Montague Plain. Rather, fire is apparently important within a pattern of species associations that is largely controlled by prior land use. For instance, pitch pine requires exposed mineral soil and open canopy conditions for successful establishment, conditions that may be met through physical disturbance such as plowing or severe fire. Because few recent fires have been severe enough to create these conditions, nearly all extant pitch pine stands are located on abandoned plowed fields. After pitch pine became established, fire contributed to its dominance on old fields.

The high frequency of extensive fires early in this century (when most stands were becoming established) probably favored pitch pine, which produces seed at a much younger age than hardwoods or white pine. Young white pine is more susceptible to fire than pitch pine and lacks the ability to resprout, an ability that is shared by pitch pine and associated hardwood species. In the absence of fire, hardwoods and especially white pine increase in number, whereas frequent light fires limit white pine and increase the understory of hardwood sprouts without disturbing the pitch pine overstory.

On unplowed sites, on the other hand, the vegetation structure varies from closed canopy hardwood-huckleberry stands to dense scrub oak thickets. We suspect that on these sites repeated cutting and burning converted formerly forested areas into shrublands: fire promotes the stability of scrub oak stands by encouraging vigorous sprouting and by removing developing tree canopies. In the absence of fire, however, hardwood trees slowly become reestablished in scrub oak stands to form an open forest canopy. Since scrub oak is intolerant of shade, this canopy eventually reduces its numbers. The continuum from scrub oak thickets to hardwood forests on unplowed sites is therefore believed to result both from fire and cutting history.

In all of these examples, a distinction remains between the vegetation of plowed sites and that of unplowed sites. We have therefore concluded that modern vegetation patterns on Montague Plain are the result of complex disturbance histories, with fire serving to modify the species assemblages that originally developed after land use was discontinued. In other words, the interactions of human, physical, and biotic factors have resulted in a remarkably heterogeneous landscape on a site with homogeneous soils.

In view of the heterogeneity of vegetation and the equally variable natural disturbance patterns in the area, conservation efforts might best focus on long-term protection of the entire landscape, rather than simply protecting the portions that currently support uncommon species. Only in this way will long-term protection of this complex, dynamic system be ensured.

Glenn Motzkin is a plant ecologist at the Harvard Forest, where David Foster is the director. Their research is reported in full in "Controlling Site to Evaluate History: Vegetation Patterns of a New England Sand Plain" by Glenn Motzkin, David Foster, Arthur Allen, Jonathan Harrod, and Richard Boone, and published in *Ecological Monographs* (1996) 66(3): 345–365.

Forest Response to Natural Disturbance Versus Human-Induced Stresses

David R. Foster, John Aber, Jerry Melillo, Richard D. Bowden, and Fakhri Bazzaz

Retrospective studies, which employ historical, archaeological, paleoecological, and dendrochronological techniques to unravel past changes in landscapes and the environment, provide one of the few opportunities for comparing forest disturbance and vegetation dynamics across major cultural and temporal boundaries. By extending our perspective from decades to millennia, historical forest reconstructions permit us to assess the effects of infrequent events, long-term trends, and gradual environmental change. They also enable us to document the successional or developmental changes in forest ecosystems that are often comprised of tree species that can live many centuries. Therefore, these assessments provide important insights into fundamental ecological processes and the provenance of modern conditions and can also serve as the basis for informed management decisions.

One important source of long-term information on forest history and dynamics in response to natural environmental change and disturbance are old-growth forests and other sites on which human impact has been minimal. Recent surveys have discovered surprisingly large numbers of old-growth stands—even in the densely populated eastern U.S.—and these forests have become an important focus of reconstructive studies on both basic and applied issues. The presence of old trees with lengthy tree-ring records of


DAVID R. FOSTER

Saplings grow between moss-covered logs of old-growth white pine and hemlock downed in the hurricane of 1938.

growth, and undisturbed sediments and soils that contain stratigraphic records of pollen, charcoal, and other semi-fossilized plant and animal materials, enable us to develop long-term site histories of disturbance and forest change.

Reconstructive studies of old-growth and other sites have revealed the remarkable resiliency of the temperate forests in the Northeast to a wide range of physical disturbances, including windthrow, fire, ice damage, and pathogens. However, a question of great interest to ecologists and with major implications for policymakers is whether these forests will be equally resilient in the face of chronic chemical and climatic stress brought on by changes in the global earth-atmosphere system. To address this question, the Harvard Forest initiated its Long Term Ecological Research (LTER) program in 1988 to analyze the effects on ecosystem structure and function of historically important natural disturbances in comparison with those of recent and projected chemical and climatic stresses.

Three disturbance and stress processes are being investigated in considerable detail: hurricane blowdowns, the chronic additions of nitrogen that occur presently as a consequence of acid rain and the burning of fossil fuels, and the warming of the soil environment that will occur as global temperatures rise with predicted climate change. To develop meaningful comparative results, we designed experimental treatments that closely simulate the major impacts of the relevant disturbances and stresses, and we chose sites in typical second-growth forests on widespread upland soils with similar forest and environmental conditions.

The Experimental Blowdown

Hurricane blowdowns cause catastrophic damage in New England forests every fifty to one hundred and fifty years. The LTER studies undertook to evaluate the effects of a storm similar to that of the 1938 hurricane on an eighty-year-old hardwood forest. To simulate a hurricane on an experimental plot, researchers used a power-driven winch to pull over in one direction, as would occur in a natural windstorm, a subset of trees comparable to those blown down in 1938.

The experimental blowdown had an immediate and dramatic impact on forest structure: the basal area (cross-sectional area of wood) and density of trees declined more than 70 percent; the average distance between canopy trees increased from 3.3 to 7.6 meters, and the maximum distance increased from 7.8 to 20.9 meters; and more than 260 new mounds and pits resulting from the uprooting of trees covered 8 percent of the soil surface.

Nonetheless, as a result of releafing and sprouting, more than 75 percent of uprooted and broken trees survived the first year and more than 40 percent continued growing after four years. Survival varied considerably according to species and extent of damage: 60 percent of yellow and black birch *(Betula alleghaniensis* and *B. lenta)* survived, as did approximately 50 percent of white pine *(Pinus strobus)* and red maple *(Acer rubrum)*, and approximately 30 percent of red oak *(Quercus rubra)*, white birch *(B. papyrifera)*, and white ash *(Fraxinus americana)*. The standing and relatively undamaged trees remaining after the blowdown showed the same low mortality rate (4 percent) as the control site for the first four years.

The extent of tree regeneration in the "blowdown" understory was high. Saplings and

JOHN O'KEEFE

A skidder's winch and cable were used at the Harvard Forest to pull down trees across a two-acre area to simulate the effects of a hurricane in 1990.

ANN LEZBERG

Researchers attach markers to a root mound upended in a simulated hurricane, 1992. The many microsites created by the uprooting of trees provide important habitat and microenvironmental diversity in the forest.

sprouts increased from fewer than 6,000 per hectare before the blowdown to nearly 8,000 per hectare one year later and to over 25,000 per hectare after three years, with only slight compositional change (birches increased, black cherry *[Prunus serotina]* and white pine declined). Increased light levels one to three meters above the ground resulted in greater growth in diameter and height of existing saplings and new sprouts on the blowdown site than on the control site.

Net ecosystem productivity declined following the experimental blowdown: in the second year, litterfall in the blowdown was only 59 percent of that found in the control site; by the fourth year, however, that number had increased to 71 percent. In general, the blowdown site underwent major reorganization of forest structure and a subtle compositional change along with rapid redevelopment of canopy cover. In contrast, and contrary to general expectation, the soil environment showed no major changes. Temperature and moisture remained the same, as did the nitrogen cycling pattern and net exchanges of important greenhouse gases between soils and the atmosphere.

The hurricane blowdown caused a marked change in the appearance of the forest, but the long-term impact on important processes was far less dramatic: it was limited to a vertical reorganization of the canopy and foliage from the top of the canopy to one to five meters above the ground. The combination of high survival rates and prolific sprouting by broken and uprooted trees, coupled with rapid growth by understory plants, resulted in rapid recovery of total leaf area and little change in the soil microenvironment, including temperature and moisture: as damaged trees died off, the growth of saplings and understory plants has provided additional leaf area. By ensuring the continuity of shade on the forest floor, floristic composition has changed less than might be expected based on successional theory and on previous studies of the 1938 storm.

From an ecosystem perspective, which seeks to examine the structure and function of forests, the blowdown experiment is highly instructive. Despite massive structural alteration of the forest, net energy and nutrient processes remained largely intact. Productivity, as measured by litterfall, declined immediately following the disturbance, but recovered rapidly within four years. The similarity of nitrogen cycling patterns, soil respiration rates, and gaseous effluxes in the control and blowdown plots indicates that changes in nutrient availability were minimal. Importantly, the maintenance of efficient cycling of nutrients suggests that the forest was able to retain these constituents despite the major physical change. Continuous vegetation production and cover provided a high degree of control by the vegetation over critical microclimatic conditions and ecosystem processes.

The Experimental Nitrogen Increases

In industrialized parts of North America and Europe, the atmospheric deposition of nitrogen has vastly increased since the 1940s as a consequence of fossil fuel combustion. In the high elevation forests of New York and New England and throughout central Europe, nitrogen deposition has been implicated in tree mortality and forest dieback. This conclusion is somewhat paradoxical because nitrogen is limiting in most terrestrial ecosystems and an increase might be expected to simply increase growth rates. How-

JOHN O'KEEFE

After the experimental blowdown, gridded frames were used to map fine-scale microtopography and to release and track tree seed as part of a study of seed dispersal. The root mound stands nearly two meters high.

ever, as nitrogen availability through acid rain exceeds demand, the ecosystem may become "saturated," basic processes may change in deleterious ways, and the excess nitrogen may leak through soils into streams and lakes. There is strong concern that this increased nitrogen will damage water quality and alter critical soil processes, including nutrient cycling and trace gas fluxes, throughout the temperate zone.

The chronic nitrogen, or nitrogen saturation, experiment was designed to examine the effects of continuous, low-level additions of nitrogen caused by acid deposition or forest ecosystem structure and function. Two stands were selected for study: a second-growth hardwood stand and a mature red pine *(Pinus resinosa)* stand. Importantly, the eighteenth- and nineteenth-century land-use history of the hardwood forest involved repeated cutting, which probably depleted nutrients on the site, whereas the red pine stand had been planted in the 1920s on an old agricultural field that had been plowed and fertilized, thereby maintaining or enhancing its natural abundance of nitrogen.

Three 30-by-30-meter plots—control (no nitrogen), low nitrogen-addition, and high nitrogen-addition—were established in each stand; nitrogen was applied in the form of ammonium nitrate in six equal monthly doses from May to October beginning in 1988. The high nitrogen-addition plots receive doses similar to levels occurring in central European countries today.

In marked contrast to the blowdown experiment, the chronic nitrogen experiment has so far produced only minimal structural changes. Tree mortality has not been affected, and species composition and canopy structure remain similar to those in control plots. However, dramatic changes in ecosystem function have occurred that may foreshadow future changes in structure.

For example, whereas the control plots retain essentially all of their nitrogen and lose none through soil leaching, the high-nitrogen pine plot has shown accelerated nitrate loss, indicative of nitrogen saturation, since year three. In the sixth year of treatment, the low-nitrogen pine plot also began showing nitrate losses. By contrast, the more nitrogen-limited hardwood stand has shown nearly total retention of nitrogen; detectable nitrate losses were not measured until year six, and then only in the high-nitrogen plot. Changes in internal carbon- and nitrogen-cycling rates and in net exchanges of methane between soils and the atmosphere have also been substantial. This result is important as it demonstrates that nitrogen excess and saturation triggers very fundamental changes in a range of ecosystem processes.

Ecophysiological theory predicts that higher concentrations of a limiting nutrient like nitrogen will lead, in turn, to higher rates of net photosynthesis and tree growth through a fertilizer effect. Indeed, more tree growth has occurred in the hardwood stand (originally nitrogen-limited), with a 45-percent increase in wood production. However, in the pine stand—where high losses from leaching suggested that nitrogen saturation occurred very rapidly—wood production over six years has been 28 percent lower than that of the control plot. Combined with even more dramatic growth declines and mortality increases in conifer stands located in high nitrogen-deposition regions of the world, these results suggest a general decrease in the vigor and wood production of conifer stands, and perhaps even the onset of serious forest decline, in response to nitrogen saturation.

The Soil-Warming Experiment

The rate of increases in global temperature that are currently projected far exceed the changes that occur naturally through glacial-interglacial cycles. One consequence of global warming may be changes in the rates of critical temperature-dependent ecosystem processes, which in turn control forest growth and health. Important soil processes that may be expected to change with increasing global temperatures include decomposition, methane production, nitrogen mineralization and nitrification, and phosphorus availability. Since many of these changes may result in the release of greenhouse gases, soil warming may itself exacerbate soil warming.

The soil-warming experiment at the Harvard Forest was designed to assess the response of a second-growth hardwood forest to elevated soil temperatures. We paid particular attention to the effects of warming on soil processes that may alter ecosystem function, atmospheric chemistry, and global climate. Eighteen 6-by-6-meter plots were established in April 1991; each was randomly assigned to one of three treatments: heated plots, in which the average soil temperature was raised 5 degrees Centigrade above ambient using buried heating cables; disturbance control plots, in which buried cables were installed but received no electrical power; and undisturbed control plots.

Initial results from the first growing season of the study indicated that heating increased emissions of carbon dioxide by 40 percent. Nitrogen cycling was also affected dramatically, with a doubling of mineralization rates in the upper soil layers. During the second and third growing seasons, warming had a much less dramatic effect on carbon dioxide emissions but a sustained dramatic effect was seen in nitrogen mineralization, which again doubled in rate.

The following scenario provides one interpretation of why the rate of carbon dioxide emissions in the heated plots relative to that of control plots decreased between the first and second years relative to disturbance control plots, whereas the rate of nitrogen mineralization continued to increase. There are two major pools of organic matter in soils, a "fast" pool and a "slow" pool. The fast pool contains material with a high ratio of carbon to nitrogen (for instance, recently fallen litter), whose decay results in relatively large losses of carbon dioxide but a small net loss of nitrogen. In contrast, the slow pool contains material with a low ratio of carbon to nitrogen (such as partially decomposed and relatively stable humus), whose decay results in a smaller loss of carbon dioxide and a larger net loss of nitrogen.

Because elevated soil temperature increases the rate of decay in the slow pool, increased amounts of both carbon and nitrogen are released. The nitrogen then becomes available for uptake by plants. However, the carbon-to-nitrogen ratio of living plant material is substantially higher than that of organic matter in the soil of the slow pool, and because of that, warming may lead to increased carbon storage in the ecosystem without increased nitrogen storage.

The study highlights the importance of long-term experiments while underscoring the potential for complex changes resulting from global climate change. Although the immediate result of soil warming is carbon release—and

JOHN O'KEEFE

One of the eighteen 6-by-6-meter plots used in the soil-warming experiment at the Harvard Forest. Heating coils placed below the soil surface raised the average temperature by five degrees Centigrade and caused subtle changes in the environment.

feedback on global change—this effect is transient. Over the longer term, the net release of nitrogen might be a much more important effect and might signal fundmental though subtle shifts in ecosystem processes.

Comparison Between the Effects of Natural Disturbances and Those of Novel Stresses

Which of these changes—"natural" disturbance or climatic and chemical stress—is actually most disruptive to the integrity of the community and most likely to lead to long-term changes in ecosystem function? Comparison of results from the three experiments led to the surprising conclusion that structural integrity—that is, the actual appearance of a forest—is not a good indicator of forest ecosystem function. Whereas the blowdown site appeared severely disturbed, fundamental internal processes were not altered significantly, and the stand is on a path to recovery of structure and function in keeping with the cyclic pattern of disturbance and regeneration in this forest type.

By contrast, the nitrogen-addition and soil-warming plots are visually intact and apparently healthy, yet the subtler measures of ecosystem function suggest serious imbalances with possible future implications for community structure, internal ecosystem processes, and exchanges with the global atmosphere.

In the nitrogen-addition plots, nitrogen losses into the deeper soil are being induced and major changes in the amounts of trace gases (carbon dioxide, methane, nitrous oxide) released from the soil to the atmosphere have occurred. In the soil-warming plots, carbon dioxide exchanges have become negative, nitrogen cycling has increased dramatically, and nitrogen losses (as nitrate) are increasing. In time, alterations in chemical or physical environments caused by these novel stresses will create changes in nitrogen concentrations and in the rates of carbon and nitrogen cycling, which in turn will alter ecosystem productivity.

We cannot predict what the ultimate trajectory of these changes will be because there is no historical analog for these experiments and none of our present-day species evolved in an environment that included these stresses. It is reasonable to believe, however, that in the long run system function will continue to be disrupted more by these novel disturbances than by natural disturbances. The plant-response mechanisms seen in the hurricane experiment, which have presumably evolved as a consequence of natural selection for recovery from natural, physical disturbance, may not exist for situations where large quantities of nitrogen are added to the soil because of human activity, or soil becomes warmer very rapidly because of climate change.

Several conclusions emerge from studies of natural ecosystems and from our experimental study of "natural" physical disturbance and novel climatic and chemical stresses: (1) all ecosystems are dynamic as a consequence of natural disturbance, natural environmental change, and human impacts; (2) as a consequence of natural changes there are no static baseline conditions for assessing current ecosystems or for establishng correct goals for environmental management; (3) ecosystems are incredibly resilient, but the rate and novel character of modern human disturbances raises the question of whether they exceed this threshold of resiliency; and (4) a comparison of hurricane disturbance, nitrogen deposition, and global change (soil warming) suggests that physical appearance is a poor indicator of ecosystem integrity and that major and deleterious changes in ecosystem function may occur as a consequence of these novel stresses.

David Foster is director of the Harvard Forest of Harvard University. John Aber is director of the Complex Systems Research Center, Institute for Study of Earth, Oceans, & Space at the University of New Hampshire. Jerry Melillo is co-director of the Ecosystem Center at the Marine Biological Laboratory of Woods Hole. Richard Bowden is assistant professor in the Department of Environmental Science, Allegheny College. Fakhri Bazzaz is H. H. Timken Professor of Science in the Department of Organismic and Evolutionary Biology of Harvard University.

This research is reported in full in "Forest Response to Disturbance and Anthropogenic Stress," published in BioScience (1997) 47(7): 437–445. This summary also draws on "Ecological and conservation insights from reconstructive studies of temperate old-growth forests" by D. R. Foster, D. A. Orwig, and J. S. McLachlan, published in *TREE: Trends in Ecology and Evolution* (1996) 11(10): 419–424.

Ecosystem Response to an Imported Pathogen: The Hemlock Woolly Adelgid

David A. Orwig and David R. Foster

One of the provocative issues that have emerged in the field of ecology over the past few decades has concerned the question of whether individual plant or animal species may play a critical role in controlling ecosystem processes and determining major community characteristics—that is, are there really "keystone" species? In an era when species are being driven either locally or globally extinct, the possibility that individual taxa may be crucial for maintaining the integrity of ecosystems has become a major impetus for the study of biodiversity.

This issue has been the focus of considerable research in the northeastern United States in particular, in large part because the region has experienced a series of species eliminations or reductions in numbers primarily as a consequence of human activities. The decline of hemlock across its range 4,800 years ago due to an insect pathogen, followed by a very gradual recovery; the elimination of chestnut in this century by a fungal blight introduced from eastern Asia; the outbreak of gypsy moth on oak, aspen, and birch forests; and the purposeful elimination or drastic reduction of animal populations—wolves, passenger pigeons, deer, beavers, to name only a few—all have undoubtedly had major consequences for forest, aquatic, and wetland ecosystems across the Northeast, although they remain largely unquantified.

Widespread, abundant, long-lived, and extraordinarily shade-tolerant, eastern hemlock *(Tsuga canadensis)* has always been classified as a preeminent part of the "climax" forest that existed before European settlement. Thanks to the extremely dense shade and deep, acidic litter it produces, hemlock is able to determine forest composition and create distinctive wildlife habitats. Although it is currently found in greatest abundance on rocky ridges or talus slopes and in moist, cool ravines, hemlock grows on a broad range of sites, and, in fact, hemlock plays an important role in controlling ecosystems all across New England, from the rocky highlands through the mesic woodlands and riparian areas, and into the wetlands.

Now, nearly 5,000 years after a pathogen decimated hemlock populations across its entire range, an introduced insect, hemlock woolly adelgid, or HWA *(Adelges tsugae)*, threatens another catastrophe for hemlock, and at the same time offers an opportunity to examine the consequences for the ecosystems it occupies. In contrast to the case of the chestnut blight, whose effects we understand only partially, we hope to learn from the case of HWA what happens to a forest when its dominant species is lost.

It is important to point out that the HWA-hemlock system behaves very differently from other pathogen and pest systems. The damage caused by HWA is unlike that of chestnut blight, gypsy moth, dutch elm disease, or the related balsam woolly adelgid *(Adelges piceae)* in that HWA attacks overstory trees, saplings, and seedlings alike, and therefore has the potential to eliminate hemlock from a site within a few years. Moreover, hemlock trees lack the ability to sprout or refoliate after defoliation; consequently reestablishment can only occur from the seedbank or from seed transported from surviving trees. Hemlock seed typically remains viable only one growing season, although a few researchers have reported seed viability for up to four years. It is believed that on most sites, episodic establishment of hemlock occurs only infrequently, under unusual

conditions related to the nature of the seedbed, moisture, and seed availability.

White-tailed deer often represent another obstacle to regeneration: many studies have shown that deer browse can severely reduce hemlock seedling densities. Deer herd density in Connecticut has more than doubled since 1980, resulting in high local population densities that change understory composition and structure. All these problems raise concerns about the long-term viability, stability, and composition of hemlock ecosystems. Many hemlock stands are scattered across the landscape on sites that have been protected from intensive human and natural disturbance. If hemlock is eliminated from even a portion of these sites, seed production will be eliminated or drastically reduced across broad geographic areas. It should be noted that it took eastern hemlock one to two thousand years to recover following the mid-Holocene decline 4,800 years ago.

In 1995 the Harvard Forest initiated a major research effort consisting of stand, landscape, and ecosystem components in central Connecticut along a 370-mile transect that extends from Long Island Sound to the Massachusetts border. To document the damage already caused by HWA since it arrived in 1985, we used aerial photographs to map each hemlock stand greater than three hectares (seven and a half acres). We have compiled extensive data on forest composition from 115 stands, which we have overlain on a GIS (Geographic Information Systems) map that shows other biological features as well as soil types and topographic characteristics. This map will facilitate our analysis of the way HWA spreads and help us determine whether the damage patterns observed in the present study are consistent across various types of landscape.

We also began to examine in detail the response of eight hemlock stands with differing levels of HWA infestation; the range of damage found in this sample was in general representative of conditions observed in dozens of stands throughout south-central Connecticut. Results after the second year of analysis of the eight sample stands showed continued deterioration of hemlock, with annual mortality levels ranging from 5 to 15 percent in stands that had already lost 20 to 95 percent of all overstory hemlock. All surviving hemlocks except those in one isolated stand are infested with HWA and have suffered moderate to severe canopy damage. Consequently, many of our study sites currently have a high proportion of standing dead snags or trees whose only remaining foliage is in the outer ends of upper branches.

In severely damaged stands, many dead treetops and boles have snapped off during recent windstorms, and deterioration in the surviving trees has continued due to

DAVID A. ORWIG

This Tsuga canadensis *branch is infested with HWA ovisacs, located along the twigs at the base of the needles.*

the presence of secondary organisms such as hemlock borer, shoestring fungi, and conk fungi. The consequences of this continued mortality will be substantial pulses of woody debris, dramatic changes in the age, structure, and composition of forests, and altered wildlife habitat. Light availability as well as above- and below-ground space should increase as HWA spreads across the landscape. We have recently begun to study how these substantial changes in forest structure will affect the timing, magnitude, and duration of nitrogen cycling.

Our analysis of the effects of HWA damage shows dramatic changes in the understory microenvironment and in the response of vegetation to these changes. Particularly in stands that previously had a high percentage of hemlock in the overstory, black birch *(Betula lenta)* seedlings have established themselves prolifically, encouraged by the increased amount of light reaching the previously shaded forest floor. The organic layer in the soil under hemlock canopies appears to be an ideal substrate for germination of this wind-dispersed species. Several researchers have reported similar increases following partial cutting or tree mortality due to chestnut blight or windthrow. An increased abundance of black birch is also expected in less severely damaged stands in the future, since it is already present in the overstory and produces copious numbers of seeds.


DAVID A. ORWIG

Severe HWA damage on the Guilford, Connecticut, study site. Note the dead hemlocks in the foreground and background, adjacent to trees that retain sparse canopies. Hemlocks typically die with their branch structures intact and gradually fall apart over three to ten years.

Seedlings of red maple and of several oak species were also present in low densities in most of our study sites; they may become more numerous in the future. The overall scarcity of hemlock seedlings in these forests suggests that neither they nor seedbanks will be of much help in hemlock reestablishment. Very few shrub species have colonized these stands; exceptions are bird-dispersed grape species *(Vitus)* and Virginia creeper *(Parthenocissus quinquefolia)*. Several opportunistic herbaceous species have also become established in low abundance throughout the study area, and invasion has already begun of several exotic tree, shrub, and herbaceous species that may increase and further affect revegetation processes in the future. Many factors, including pre-HWA site and soil characteristics, hemlock mortality rates, herbivore pressure, and the percentage of overstory space occupied by hardwood species, will also

DAVID A. ORWIG

Black birch seedlings have established themselves prolifically under HWA-damaged hemlocks, encouraged by the increased amount of light reaching the previously shaded forest floor.

play a role in determining the eventual composition of vegetation.

By documenting damage patterns and changes in forest structure and composition resulting from an introduced forest pest as they develop, we have gained valuable insight into the initial recovery processes of forests when a dominant species is removed. The results of this study and direct observations in dozen of stands throughout the state indicate that Connecticut forests are being severely impacted by HWA. To date, the rate and intensity of infestation is not attributable to any site factor or stand characteristic, and there is no apparent impediment to the widespread expansion of HWA and devastation of eastern hemlock across its range.

Varying degrees of HWA infestation at the stand level resulted in high hemlock mortality rates, pulses of downed woody debris, and dramatic changes in microenvironment characteristics due to overstory canopy gaps. These structural changes have initiated rapid vegetation responses in understories typically devoid of vegetation. In addition, our results suggest that some sites may experience a complete change in cover type from hemlock to forests dominated by birch, oak, and maple species. Under this scenario, forest composition and structure at the landscape level would become increasingly more homogenous. The outlook for hemlock persistence in southern New England forests is bleak. If HWA dispersal continues unimpeded, dramatic reductions of hemlock across broad geographical areas appear imminent unless natural or introduced predators of HWA are found.

David A. Orwig is a forest ecologist at the Harvard Forest, where David R. Foster is the director. Their research has been published in full in "Forest Response to the Introduced Hemlock Woolly Adelgid in Southern New England, USA" in *Journal of the Torrey Botanical Society* (1998) 125(1): 60–73.

arnoldia

The Magazine of the Arnold Arboretum

arnoldia

Volume 58 Number 3 1998

Arnoldia (ISSN 004–2633; USPS 866–100) is published quarterly by the Arnold Arboretum of Harvard University. Second-class postage paid at Boston, Massachusetts.

Subscriptions are $20.00 per calendar year domestic, $25.00 foreign, payable in advance. Most single copies are $5.00. Remittances may be made in U.S. dollars, by check drawn on a U.S. bank; by international money order; or by Visa or Mastercard. Send orders, remittances, change-of-address notices, and all other subscription-related communications to: Circulation Manager, *Arnoldia*, The Arnold Arboretum, 125 Arborway, Jamaica Plain, Massachusetts 02130–3500. Telephone 617/524–1718; facsimile 617/524–1418; e-mail arnoldia@arnarb.harvard.edu.

Postmaster: Send address changes to
Arnoldia Circulation Manager
The Arnold Arboretum
125 Arborway
Jamaica Plain, MA 02130–3500

Karen Madsen, *Editor*
Andy Winther, *Designer*

Page

2 In the Shadow of Red Cedar
Wade Davis

11 The First and Final Flowering of Muriel's Bamboo
Peter Del Tredici

18 Nature Study Moves into the Twenty-First Century
Candace L. Julyan

25 Native vs. Nonnative: A Reprise
Letters to the Editor

30 Native Plants: Another View
Harrison L. Flint

Front cover: Bigleaf maples *(Acer macrophyllum)* on Washington State's Olympic Peninsula photographed by Graham Osborne.

Inside front cover: Branchlets and cones of western red cedar *(Thuja plicata)*. Photograph by Peter Del Tredici.

Inside back cover: Bunchberry *(Cornus canadensis)* and ferns in Skagit Valley, Washington. Photograph by Graham Osborne.

Back cover: Western red cedar and hemlocks *(Tsuga heterophylla)* in Mt. Rainier National Park, Washington. Photograph by Graham Osborne.

GRAHAM OSBORNE

In the Shadow of Red Cedar

Wade Davis

In the shadow of red cedar, along a stream colored by salmon, in a place where plants draw food from the air and small creatures living on dew never touch the forest floor, it is difficult to imagine a time when the coastal temperate rainforests of North America did not exist. Today, these immense and mysterious forests, which in scale and wonder dwarf anything to be found in the tropics, extend in a vast arc from northern California 2,000 miles north and west to the Copper River and the Gulf of Alaska. Home to myriad species of plants and animals, a constellation of life unique on earth, they spread between sea and mountain peak, reaching across and defying national boundaries as they envelop all who live within their influence in an unrivaled frontier of the spirit.

It is a world anchored in the south by giant sequoias *(Sequoiadendron giganteum)*, the most massive of living beings, and coast redwoods *(Sequoia sempervirens)* that soar 300 feet above the fogbanks of Mendocino. In the north, two trees flourish: western hemlock *(Tsuga heterophylla)*, with its delicate foliage and finely furrowed bark; and Sitka spruce *(Picea sitchensis)*, most majestic of all, a stunningly beautiful species with blue-green needles that are salt tolerant and capable of extracting minerals and nutrients from sea spray. In between, along the silent reaches of the midcoast of British Columbia, behind a protective veil of Sitka spruce, rise enormous stands of Douglas fir *(Pseudotsuga menziesii)*. Intermingled with hemlock and fir, growing wherever the land is moist and the rains abundant, is perhaps the most important denizen of the Pacific slope, the western red cedar *(Thuja plicata)*, the tree that made possible the florescence of the great and ancient cultures of the coast.

To walk through these forests in the depths of winter, when the rain turns to mist and settles softly on the moss, is to step back in time. Two hundred million years ago vast coniferous forests formed a mantle across the entire planet. Dinosaurs evolved long supple necks to browse high among their branches. Then evolution took a great leap, and flowers were born. What made them remarkable was a mechanism of pollination and fertilization that changed the course of life on earth. In the more primitive conifers, the plant must produce the basic food for the seed with no certainty that it will be fertilized. In the flowering plants, by contrast, fertilization itself sparks the creation of the seed's food reserves. In other words, unlike the conifers, the flowering plants make no investment without the assurance that a viable seed will be produced. As a result of this and other evolutionary advances, the flowering plants came to dominate the earth in an astonishingly short time. Most conifers went extinct, and those that survived retreated to the margins of the world, where a small number of species maintained a foothold by adapting to particularly harsh conditions. Today, at a conservative estimate, there are over 250,000 species of flowering plants. The conifers have been reduced to a mere 700 species, and in the tropics, the hotbed of evolution, they have been almost completely displaced.

On all the earth, there is only one region of any size and significance where, because of particular climatic conditions, the conifers retain their former glory. Along the northwest coast of North America the summers are hot and dry, the winters cold and wet. Plants need water and light to create food. Here in the summer there is ample light for photosynthesis but not enough water for most deciduous trees, except in low-lying areas where broadleafed species such as red alder *(Alnus rubra)*, cottonwood *(Populus balsamifera* ssp. *trichocarpa)*, and vine maple *(Acer circinatum)* flourish. In the winter, when

---

Western red cedar and hemlock in Stoltmann Wilderness, British Columbia.

both water and light are sufficient, the low temperatures cause the flowering plants to lose their leaves and become dormant. The evergreen conifers, by contrast, are able to grow throughout the long winters, and since they use water more efficiently than broadleafed plants, they also thrive during the dry summer months. The result is an ecosystem so rich and so productive that the biomass in the best sites is easily four times as great as that of any comparable area of the tropics.

Indeed it is the scale and abundance of the coastal rainforests that overwhelm the visitor. White pine *(Pinus strobus)*, the tallest tree of the eastern deciduous forests, barely reaches two hundred feet; in the coastal rainforests there are thirteen species that grow higher, with the redwoods reaching nearly four hundred feet, taller than a twenty-five-story building. Red cedars can be twenty feet or more across at the base. The footprint of a Douglas fir would crush a small cabin. The trunk of a western hemlock, a miracle of biological engineering, stores thousands of gallons of water and supports branches festooned with as many as 70 million needles, all capturing the light of the sun. Spread out on the ground, the needles of a single tree would create a photosynthetic surface ten times the size of a football field.

These giant trees delight, but the real wonder of the forest lies in the details, in the astonishingly complex relationships: a pileated woodpecker living in the hollow of a snag, tiny seabirds laying their eggs among the roots of an ancient cedar, marbled murrelets nesting in a depression in the moss in the fork of a canopy tree, rufous hummingbirds returning each spring, their migrations timed to coincide with the flowering of salmonberries *(Rubus spectabilis)*. In forest streams dwell frogs with tails and lungless salamanders that live by absorbing oxygen through their skin. Strange amphibians, they lay their eggs not in water but on land, in moist debris and fallen logs.

Invertebrate life is remarkably diverse. The first survey to explore systematically the forest

GRAHAM OSBORNE

Vine maples, Acer circinatum, *near Lake Mills, Washington.*

GRAHAM OSBORNE

Mossy branches of bigleaf maple, Acer macrophyllum, *Olympic Peninsula, Washington.*

canopy in the Carmanah Valley of Vancouver Island yielded 15,000 species, a third of the invertebrates known to exist in all of Canada. Among the survey's collections were 500 species previously unknown to science. Life is equally rich and abundant on the forest floor. There are 12 species of slugs, slimy herbivores that in some areas account for as much as seventy percent of the animal biomass. A square meter of soil may support 2,000 earthworms, 40,000 insects, 120,000 mites, 120,000,000 nematodes, and millions upon millions of protozoa and bacteria, all alive, moving through the earth, feeding, digesting, reproducing, and dying.

None of these creatures, of course, lives in isolation. In nature, no event stands alone. Every biological process, each chemical reaction, leads to the unfolding of other possibilities for life. Tracking these strands through an ecosystem is as complex as untangling the distant threads of memory from a myth. For years, even as industrial logging created clearcuts the size of small nations, the coastal rainforests were among the least studied ecosystems on the planet. Only within the last decade or two have biologists begun to understand and chart the dynamic forces and complex ecological relationships that allow these magnificent forests to exist.

One begins with wind and rain, the open expanse of the Pacific and the steep escarpment of mountains that makes possible the constant cycling of water between land and sea. Autumn rains last until those of spring, and months pass without a sign of the sun. Sometimes the rain falls as mist, and moisture is raked from the air by the canopy of the forest. At other times the storms are torrential, and daily precipitation is measured in inches. The rains draw nutrients from the soil, carrying vital food into rivers and streams that fall away to the sea and support the greatest coastal marine diversity on earth. In the estuaries and tidal flats of British Columbia, in shallows that merge with the wetlands, are six hundred types of seaweed, seventy species of sea stars. Farther offshore, vast, underwater kelp forests shelter hundreds of forms of life, which in turn support a food chain that reaches into the sky to nourish dozens of species of seabirds.

The land provides for life in the sea, but the sea in turn nurtures the land. Birds deposit

excrement in the moss, yielding tons of nitrogen and phosphorus that are washed into the soil by winter rains. Salmon return by the millions to their native streams, providing food for eagles and ravens, grizzly and black bears, killer whales, river otters, and more than twenty other mammals of the sea and forest. Their journey complete, the sockeye and coho, chinooks, chums, and pinks drift downstream in death and are slowly absorbed back into the nutrient cycle of life. In the end there is no separation between forest and ocean, between the creatures of the land and those of the sea. Every living thing on the raincoast ultimately responds to the same ecological rhythm. All are interdependent.

The plants that dwell on land nevertheless face particular challenges, especially that of securing nutrients from thin soils leached by rain throughout much of the year. The tangle of ecological adaptations that has evolved in response is nothing short of miraculous. As much as a fifth of the biomass in the foliage of an old-growth Douglas fir, for example, is an epiphytic lichen, *Lobaria oregana*, which fixes nitrogen directly from the air and passes it into the ecosystem. The needles of Sitka spruce absorb phosphorus, calcium, and magnesium, and their high rate of transpiration releases moisture to the canopy, allowing the lichens to flourish.

On the forest floor thick mats of sphagnum and other mosses filter rainwater and protect the mycelia of hundreds of species of fungi; these elements form one of the richest mushroom floras on earth. Mycelia are the vegetative phase of a fungus, small hairlike filaments that spread through the organic layer at the surface of the soil, absorbing food and precipitating decay. A mushroom is simply the fruiting structure, the reproductive body. As the mycelia grow, they constantly encounter tree roots. If the species combination is the right one, a remarkable biological event unfolds. Fungus and tree come together to form mycorrhizae, a symbiotic partnership that allows both to benefit. The tree provides the fungus with sugars created from sunlight. The mycelia in turn enhance the tree's ability to absorb nutrients and water from the soil. They also produce growth-regulating chemicals that promote the production of new roots and enhance the immune system. Without this union, no tree could thrive. Western hemlocks are so dependent on mycorrhizal fungi that their roots barely pierce the surface of the earth, even as their trunks soar into the canopy.

The story only gets better. All life requires nitrogen for the creation of proteins. Nitrates, a basic source, are virtually absent from the acidic, heavily leached soils of the rainforest. The mycorrhizae, however, contain not only nitrogen-fixing bacteria that produce this vital raw material but also a yeast culture that promotes the growth of both the bacteria and the fungus. There are scores of different mycorrhizae—the roots of a single Douglas fir may have as many as forty types—and, like any other form of life, the fungus must compete, reproduce, and find a means to disperse its spore. The fruiting body in many cases is an underground mushroom or a truffle. When mature, it emits a pungent odor that seeps through the soil to attract rodents, flying squirrels, and red-backed voles, delicate creatures that live exclusively on a refined diet of truffles. As the voles move about the forest, they scatter droppings, neat little bundles of feces that contain yeast culture, fungal spores, and nitrogen-fixing bacteria—in short, all that is required to inoculate roots and prompt the creation of new mycorrhizae.

Fungi bring life to the forest both by their ability to draw nutrients to the living and by their capacity to transform the dead. In old-growth forests twenty percent of the biomass—as much as six hundred tons per hectare—is retained in fallen debris and snags. There is as much nutrition on the ground as there is within it. The moss on the forest floor is so dense that virtually all seedlings sprout from the surface of rotting stumps and logs, which may take several hundred years to decay.

When a tree falls in the forest, it is immediately attacked by fungi and a multitude of insects. The wood provides a solid diet of carbohydrates. To secure proteins and other nutrients, the fungi deploy natural antibiotics to kill nitrogen-fixing bacteria. Chemical attractants emitted by the fungi draw in other prey, such as nematode worms, which are dispatched with exploding poison sacs and an astonishing arse-

Western red cedar near Port Angeles, Washington.

GRAHAM OSBORNE

Douglas firs at sunrise.

nal of microscopic weapons. The assault on the log comes from many quarters. Certain insects, incapable of digesting wood directly, exploit fungi to do the work. Ambrosia beetles, for example, deposit fungal spores in tunnels bored into the wood. After the spores germinate, the tiny insects cultivate the mushrooms on miniature farms that flourish in the dark.

In time other creatures appear—mites and termites, carpenter ants that chew long galleries in the wood and establish captive colonies of aphids that produce honeydew from the sap of plants. Eventually, as the log progresses through various stages of decay, other scavengers join the fray, including those that consume white cellulose, turning wood blood-red and reducing the heartwood to dust. An inch of soil may take a thousand years to accumulate. Organic debris may persist for centuries. Dead trees are the life of the forest, but their potential is realized only slowly and with great patience.

This observation leads to perhaps the most extraordinary mystery of all. Lush and astonishingly prolific, the coastal temperate rainforests are richer in their capacity to produce the raw material of life than any other terrestrial ecosystem on earth. The generation of this immense natural wealth is made possible by a vast array of biological interactions so complex and sophisticated as to suggest an evolutionary lineage drifting back to the dawn of time. Yet all evidence indicates that these forests emerged only within the last few thousand years. In aspect and species composition they may invoke the great coniferous forests of the distant geologic past, but as a discrete and evolving ecosystem the coastal temperate rainforests are still wet with the innocence of birth.

Some twenty thousand years ago, what is today British Columbia was a place of turmoil and ice. The land was young, unstable, given to explosive eruptions that burst over the shore. A glacial sheet more than 6,000 feet deep covered the interior of the province, forging mountains and grinding away valleys as it moved over the land, determining for all time the fate of rivers. On the coast, giant tongues of ice carved deep fjords beneath the sea. The sea levels fell by 300 feet, and the sheer weight of ice depressed the shoreline to some 750 feet below its current level. Fourteen thousand years ago, an instant in geologic time, the ice began to melt, and the glaciers retreated for the last time. The ocean invaded the shore, inundating coastal valleys and islands. But the land, freed at last of the weight of eons, literally sprang up. Within a mere one thousand years, the water drained

back into the sea, and the coastline became established more or less as it is today.

Only in the wake of these staggering geological events did the forests come into being. At first the land was dry and cold, an open landscape of aspen and lodgepole pine *(Pinus contorta).* Around ten thousand years ago, even as the first humans appeared on the coast, the air became more moist and Douglas fir slowly began to displace the pine. Sitka spruce flourished, though hemlock and red cedar remained rare. Gradually the climate became warmer, with long seasons without frost. As more and more rain fell, endless banks of clouds sheltered the trees from the radiant sun. Western hemlock and red cedar expanded their hold on the south coast, working their way north at the expense of both fir and Sitka spruce.

For the first people of the raincoast, this ecological transition became an image from the dawn of time, a memory of an era when Raven slipped from the shadow of cedar to steal sunlight and cast the moon and stars into the heavens. Mythology enshrined natural history, for it was the diffusion of red cedar that allowed the great cultures of the Pacific Northwest to emerge. The nomadic hunters and gatherers who for centuries had drifted with the seas along the western shores of North America were highly adaptive, capable of taking advantage of every new opportunity for life. Although humans had inhabited the coast for at least five thousand years, specialized tools first appear in the archaeological record around 3000 B.C., roughly the period when red cedar came into its present dominance in the forests. Over the next millennium, a dramatic shift in technology and culture occurred. Large cedar structures were in use a thousand years before the Christian era. A highly distinct art form developed by 500 B.C. Stone mauls and wooden wedges, obsidian blades and shells honed to a razor's edge allowed the highly durable wood to be worked into an astonishing array of objects, which in turn expanded the potential of the environment.

* * *

In Oregon and Washington only ten percent of the original coastal rainforest remains. In California only four percent of the redwoods have been set aside. In British Columbia, roughly sixty percent has been logged, largely since 1950. In the last two decades, over half of all timber ever extracted from the public forests of British Columbia has been taken. At current rates of harvest, roughly 1.5 square miles of old growth per day, the next twenty years will see the destruction of every unprotected valley of ancient rainforest in the province.

In truth, no one really knows what will happen to these lands once they are logged. Forests are extraordinarily complex ecosystems. Biologists have yet to identify all of the species, let alone understand the relationships among them. Although we speak with unbridled confidence of our ability to reproduce the ecological conditions of a forest and to grow wood indefinitely, there is no place on earth that is currently cutting a fourth generation of timber on an industrial scale. The more imprecise a science, the more dogmatically its proponents cling to their ability to anticipate and predict phenomena.

Forestry as traditionally practiced in the Pacific Northwest is less a science than an ideology, a set of ideas reflecting not empirical truths, but the social needs and aspirations of a closed group of professionals with a vested interest in validating its practices and existence. The very language of the discipline is disingenuous, as if conceived to mislead. The "annual allowable cut" is not a limit never to be exceeded but a quota to be met. The "fall down effect," the planned decline in timber production as the old growth is depleted, is promoted as if it were a natural phenomenon when it is in fact a stunning admission that the forests have been drastically overcut every year since modern forestry was implemented in the 1940s. "Multiple-use forestry"—which implies that the forests are managed for a variety of purposes, including recreation, tourism, and wildlife—begins with a clearcut. Old growth is "harvested," though it was never planted and no one expects it to grow back. Ancient forests are "decadent" and "overmature," when by any ecological definition they are at their richest and most biologically diverse state.

The most misleading of these terms is "sustained yield," for it has led the public to believe that the trees are growing back as fast as they are being cut. But they are not. In British

Columbia alone there are 8.7 million acres of insufficiently restocked lands. We continue to cut at a rate of 650,000 acres per year. Every year 2.5 million logging-truck loads roll down the highways of the province. Lined up bumper to bumper, they would encircle the earth twice. In practice, sustained-yield forestry remains an untested hypothesis: after three generations we are still cutting into our biological capital, the irreplaceable old-growth forests. As a scientific concept, sustained yield loses all relevance when applied to an ecological situation the basic parameters of which remain unknown. At best, sustained yield is a theoretical possibility; at worst, a semantic sleight of hand, intended only to deceive.

Anyone who has flown over Vancouver Island, or seen the endless clearcuts of the interior of the province, grows wary of the rhetoric and empty promises of the forest industry. Fishermen and women become skeptical when they learn that logging has driven 142 salmon stocks to extinction and left 624 others on the brink. Timber for British Columbia mills now comes from Manitoba. Truck drivers from Quesnel, a pulp-and-paper town in the center of the province, haul loads hundreds of miles south from Yukon. Just one of the clearcuts southeast of Prince George covers five hundred square kilometers, five times the area of the city of Toronto. This, after sixty years of official commitment to sustained-yield forestry. The lament of the old-time foresters—that if only the public understood, it would appreciate what we do—falls flat. The public understands but does not like what it sees.

Fortunately, this orthodoxy is now being challenged. Many in the Pacific Northwest, including the best and brightest of professional foresters, recognize the need to move beyond, to an era in which resource decisions are truly based on ecological imperatives, in which the goal of economic sustainability is transformed from a cliché into an article of faith. To make this transition will not be easy, and it will involve much more than tinkering with the edges of an industry that generates $15.9 billion a year in the province of British Columbia alone. Dispatching delegations to Europe to reassure customers, or devising new regulations that if implemented may mitigate some of the worst ecological impacts, will neither restore the public's confidence and trust nor address the underlying challenge of transforming the economy.

Any worker who has wielded a saw or ripped logs from a setting knows that in the end it all comes down to production. The enormous wealth generated over the last fifty years has been possible only because we have been willing to indulge egregious practices in the woods that have little to do with the actual promise of forestry. Spreading clearcuts ever deeper into the hinterland is a policy of the past, crude and anachronistic, certain to lead to a dramatic decline in the forestry sector and to bitterness and disappointment in the communities that rely upon the forests for both spiritual and material well-being. Revitalizing cutover lands with vibrant tree plantations, implementing intensive silviculture to increase yields, establishing the finest model of forest management on a finite land base—these are initiatives that will both allow communities to prosper and enable them to fulfill a moral obligation to leave to the future as healthy an environment as the one they inherited.

There is no better place to pursue a new way of thinking than in the temperate rainforests of the coast. At the moment, less than six percent has been protected; the remainder is slated to be logged. If anything, this ratio should be reversed. We live at the edge of the clearcut; our hands will determine the fate of these forests. If we do nothing, they will be lost within our lifetimes, and we will be left to explain our inaction. If we preserve these ancient forests, they will stand for all generations and for all time as symbols of the geography of hope. They are called old growth not because they are frail but because they shelter all of our history and embrace all of our dreams.

Wade Davis is an ethnobotanist and prolific writer. This article is excerpted from his most recent book, *Shadows in the Sun: Travels to Landscapes of Spirit and Desire*, published by Island Press/Shearwater Books (1.800.828.1302 or www.islandpress.org).

Photographer Graham Osborne specializes in alpine and coast subjects. The photographs in this article and on the covers have been published in his book *Rainforest*, published by Chelsea Green, Vermont.

The First and Final Flowering of Muriel's Bamboo

Peter Del Tredici

Muriel's bamboo, Fargesia murielae, *in the full flush of its spring growth.*

Regular readers of *Arnoldia* can appreciate the many satisfactions that come from working at the Arnold Arboretum, with its endless opportunities for studying plants. Even after twenty years of daily contact, there's always something new and exciting. Some days it is the first flowers on a recently planted specimen; on others, it is stumbling, sometimes quite literally, across an amazing old plant never before noticed. The highlight of the 1998 season was definitely the discovery of flowers on Muriel's bamboo, *Fargesia murielae,* which appeared at the Arnold Arboretum for the first—and last—time.

The Flowering

Fargesia murielae is native to the mountains of central China, where it grows at elevations between two and three thousand meters. The species is one of the principal foods of the giant panda bear and arguably one of the most ornamental of the hardy species of bamboo. Its graceful, arching stems reach two to three meters in height and add a measure of exotic elegance to any garden. As a clump-forming species it expands slowly, in stark contrast to bamboos that spread by long, underground stems—the "running bamboos"—which are often the bane of unwary gardeners. Experienced bamboo growers are universal in their praise of *Fargesia murielae,* not only for the above-mentioned traits, but also because Muriel's bamboo is among the hardiest of the entire family, growing well in USDA zone 5 and, with protection, into zone 4.

For all of its attractiveness, however, the most interesting feature of Muriel's bamboo is its monocarpic life cycle—it flowers once in its life and then dies. Gardeners are used to seeing sunflowers germinate, grow, and die in a single season, and foxgloves die after two years, but the idea of a plant flowering after eighty to one hundred years and then dying seems more than a little strange. And strange indeed it is, being found only among the "woody" monocots, such as the well-known century plant (*Agave* sp.),

a few genera of palms (most notably in the genus *Corypha*), and an Andean bromeliad of tree-sized proportions (*Puya raymondii*), which tend to come into flower when they reach a critical size.[1]

Monocarpic bamboos are unique even among this unusual group because they do not flower according to their size, but according to a predetermined maturation cycle, the length of which appears to be genetically fixed for each species.[2] The eighty-to-one-hundred-year flowering cycle of Muriel's bamboo, while certainly not the longest on record, is among the most widely known and well documented. Indeed, it was the widespread flowering and subsequent death of the umbrella bamboo in China in 1971, along with that of several closely related species, that created worldwide concern about the survival of the giant panda. The panda population in central China, it was found, had become overly dependent on the high-elevation species of *Fargesia* after bamboo species growing at lower elevations were eliminated by land clearance for agriculture.[3]

Even more remarkable than their long flowering cycle, many bamboos are also synchronous in their flowering behavior. This term refers to the tendency of most or all of the individuals of a given species to come into flower at more or less the same time. This unusual behavior has led some authors to postulate that flowering in these bamboos is controlled not by climatic factors but by some sort of internal clock. In reality, however, the synchronicity is less precise than generally believed, particularly when plants in their native habitat are compared with same-aged cohorts in cultivation that have been repeatedly propagated by division.[4] It may be propagation by subdivision that affects cultivated bamboos, but in any case their flowering cycle occurs as much as twenty years later.

While many authors have speculated on the possible evolutionary and ecological significance of the monocarpic habit in bamboos, nothing has been proved. One theory, proposed by Daniel Janzen,[5] is that the long delay in flowering is a strategy for preventing a buildup of predators that would feed on the highly nutritious seeds if they were produced on a predictable schedule. However, this idea does not explain why the flowering intervals of many bamboos greatly exceed the lifespans of most animals that would feed on their seeds. More likely, the real reason is inextricably embedded in a complex matrix of physiological, ecological, and evolutionary factors.

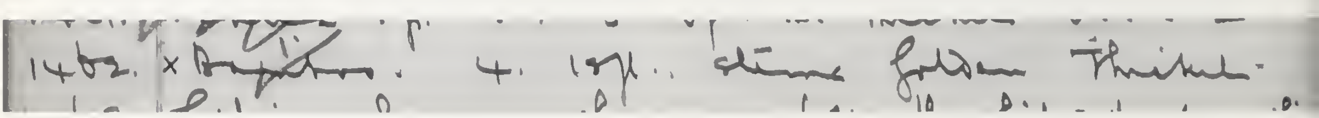
The Introduction

The history of the plant's introduction into cultivation in the West, like that of so many other plants, is cloaked in mystery and confusion. It was first collected by the Arnold Arboretum's most famous plant collector, E. H. Wilson, who assigned it number 1462. The Arboretum has most of Wilson's field books in its archives, and those for his first Arboretum expedition, from February 1907 through April 1909, contains the following entry: "1462. Bamboo, 12 ft., stems golden, thickets, 7000–9000 ft, Fang. Plants, __ __ __."[6] Unfortunately, the last three words of the passage are unintelligible, but one important piece of information is unequivocal: living plants, along with the usual herbarium specimens, were part of this collection.

With the help of Alfred Rehder, Wilson reworked his field notes and published them in *Plantae Wilsonianae*,[7] a work in three volumes that appeared in sequence in 1913, 1916, and 1917. The reference to the umbrella bamboo occurs on page 64 of volume II:

> *Arundinaria* sp. Western Hupeh: Fang Hsien, uplands, alt. 2000–3000 m., April 17, 1907 (No. 1462; 2–4 m. tall, stems golden). Without flowers. This plant is in cultivation. It forms on the mountains of north-western Hupeh dense thickets and with its clear golden slender stems is one of the most beautiful of Chinese Bamboos. A picture will be found under No. 0111 of the collection of my photographs. E.H.W."[8]

The photograph that Wilson referred to is found in a bound volume entitled "Arnold Arboretum Second Expedition to China: 1910–1911.



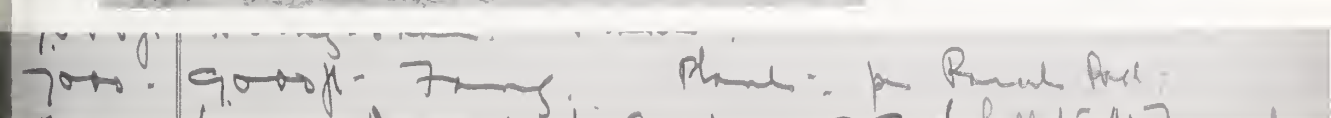
Photographs by E. H. Wilson." Photograph #0111 clearly shows a clump-forming bamboo growing below a group of fir trees *(Abies fargesii)*. According to the notes on the accompanying label, the photograph was taken on June 19, 1910, and the plant, Wilson's #1462, is seen growing "behind Fang Hsien" at an altitude of 8,000 feet. Wilson's diary for this day includes the following entry:

> The rain had ceased when we woke at 5 am & though dark mist obscured everything from a hundred yards above & around us I prophesied a fine day. It remained fine for about two hours & then commenced to rain steadily. It increased as the day advanced & we had a fine soake. All were soon drenched to the skin & everything became sodden. We hurried on as fast as possible & reached the head of the pass at 10 am . . . Much of the Bamboo has been burned and cut away from the path which is considerable improved since our last visit . . . This bamboo is the handsomest I know with its bright golden yellow culms some 10–15 ft high shrubs and with arching plume. It must be very hardy for the climate here is very rigorous. Patches of original forest remain here and there & especially near watercourse silver fir & many Birch with willows and Rhod. are practically the sole constituents.

The final reference to bamboo #1462 in the Arboretum archives comes from an undated notebook in Wilson's own handwriting entitled: "Numerical list of seeds [no. 1–1474, 4000–4462], collected on his Arnold Arboretum expeditions to eastern Asia, 1907–09, 1910, which were planted in the arboretum nurseries."[9] Under #1462, a single bamboo plant is listed as being located in the "Greenhouse & Frames" area of the nurseries. Unfortunately, the Arboretum's permanent records of plants growing on the grounds do not contain any mention of #1462, strongly suggesting that the plant was never cultivated out-of-doors.

ARCHIVES OF THE ARNOLD ARBORETUM

Fargesia murielae *photographed by E. H. Wilson in its native habitat, Fang Hsien, China, at 8,000 feet. The plants are ten to fifteen feet high with yellow culms.* Abies fargesia *stand in the background. Below is Wilson's field book entry for collection #1462.*



The first scientific description of Wilson's #1462 did not appear until 1920, in an article in *Kew Bulletin of Miscellaneous Information,*[10] under the name *Arundinaria murielae* Gamble. In the notes following J. S. Gamble's Latin description, W. J. Bean, Kew horticulturist, noted that, "By Mr. Wilson's special wish the species is dedicated to his daughter, Muriel Wilson." Bean went on to detail the plant's history:

> This Bamboo was presented to Kew from the Arnold Arboretum in the autumn of 1913. A single plant came in a pot, and this was divided up into about half a dozen pieces, which were repotted and grown for a few months in a greenhouse. They were then planted out in the collection of Bamboos near the Rhododendron Dell where they have grown luxuriantly and promise to be as ornamental as any hardy species. They are at present (October 1920) about 8 ft. high forming dense masses of culms, the outer ones of which arch outwards towards the top and give the plants a very graceful appearance . . . On the whole *A. murielae* is a distinct and most attractive addition to hardy bamboos.

At the Royal Botanic Garden, Kew, the only record of Wilson's #1462 is in the accession books, which noted its arrival on December 12, 1913.

Wilson's only other reference to #1462 is in *A Naturalist in Western China,* published in London in 1913 and New York in 1914. On page 49 he describes the vegetation behind Fang Xian by paraphrasing his journal entry of June 19, 1910:

> The summit is of hard limestone with rare outcroppings of red sandstone. Stunted windswept Silver Fir and various kinds of Currant extend to the summit. Rhododendron and a dwarf Juniper *(J. squamata)* are also common. The descent was through woods of Birch and Bamboo to an open, grassy, scrub-clad, sloping moorland, through which a considerable torrent flows. The Bamboo, so common hereabouts, is very beautiful, forming clumps 3 to 10 feet through. The culms are 5 to 12 feet tall, golden yellow, with dark, feathery foliage; the young culms have broad sheathing bracts protecting the branchlets. Taken all in all, this is the handsomest Bamboo I have seen.[1]

The footnote at the bottom of the page reads: "In 1910 I successfully introduced it into cultivation." In the revised edition of the book, published in 1929 under a new title, *China, Mother of Gardens,* Wilson makes clear that the nameless bamboo mentioned in the 1913 edition was collection #1462 by removing the footnote and adding the following to the end of the above-quoted paragraph: "In 1910, I successfully introduced it into cultivation. It has been named Arundinaria Murielae in compliment to my daughter."[11]

From all this information, it appears that only one plant of Wilson's #1462, collected on May 17, 1907, survived the long journey from Fang Xian in China to the Arnold Arboretum, where it was observed growing in the greenhouse in 1910. In December 1913, without ever being cultivated out-of-doors here, the plant was sent to Kew Gardens where it was divided—it must have been quite large—and planted out in the bamboo collection. Although *Fargesia murielae* was widely distributed throughout Europe during the first part of the century, the Arnold Arboretum did not get another plant until 1960, when the U.S. National Arboretum in Washington, D.C., sent one (under the name *Sinarundinaria murielae*) that had been imported in 1959 from the Royal Moerheim Nurseries in Dedemsvaart, Holland.[12]

Flowers at Last

The first flowers of *Fargesia murielae* in the West appeared in Denmark in 1975.[13] While these plants were clearly representative of the species, it is not certain that they were part of Wilson's #1462 clone. The plants were said to be smaller than Wilson's, and they came into bloom several years earlier than plants known to be divisions of #1462.

While the origin of the Danish plants will never be determined with certainty, the fact remains that in 1998 the flowering of known clones of Wilson's *Fargesia murielae* appears to be virtually complete, more than ninety years after it was collected from the wild. Some of the plants of #1462 have produced seed, but it is important to remember that they are the result of self-pollination, and as such they are likely to suffer from the deleterious effects of inbreeding depression. Only by re-collecting the species in central China—from seedlings that germinated following the widespread flowering that

History of *Fargesia murielae* in the West

1892: The French missionary P. Farges collects a herbarium specimen of an unknown flowering bamboo in Szechuan Province, China. In 1893, the French taxonomist A. Franchet assigns it to a new genus, *Fargesia,* with the specific name *spathacea.*[14]

17 May 1907: On his first expedition to China for the Arnold Arboretum, E. H. Wilson collects plants and three sterile herbarium specimens of an unknown bamboo at Fang Xian, Hubei, under collection #1462.

[1910]: Wilson makes note of a single plant from his collection #1462 growing in the "greenhouses and frames" area of the Arnold Arboretum.

10 June 1910: On his second Arboretum expedition to China, Wilson revisits Fang Xian and photographs #1462, labelling the photograph #0111.

12 December 1913: One plant of Wilson's #1462 is received by Kew Gardens from the Arnold Arboretum. The plant is divided into six pieces that are planted out in the bamboo area.

1916: Wilson labels #1462 as *Arundinaria* sp. in volume II of *Plantae Wilsonianae,* but lists the wrong collection date.

1920: Wilson's #1462 is given the name *Arundinaria murielae* by J. S. Gamble.

1935: T. Nakai of Japan reclassifies *Arundinaria murielae* as *Sinarundinaria murielae.*

23 December 1959: U.S. National Arboretum botanist F. Meyer arranges for the importation of plants of *Sinarundinaria murielae* (PI #262266) from the Royal Moerheim Nurseries, Dedemsvaart, Holland. The plants are probably divisions of Wilson's #1462. One of them is received by the Arnold Arboretum on 8 November 1960, under accession #1239-60.

1975: Plants of *Sinarundinaria murielae* in Denmark, possibly divisions of Wilson's #1462, come into flower.

1979: Based on the flowering specimens of the Danish plants, T. Soderstrom proposes the name *Thamnocalamus spathaceus,* for the umbrella bamboo. Based on the same specimens, other botanists argue that the species should be classified as either *Fargesia murielae* (Gamble) or *F. spathacea* (Franchet).

1988: At Kew Gardens, the original plants of Wilson's #1462 come into flower for the first time.

1995: C. Stapleton makes the case for preserving the name *Fargesia murielae,* but proposes correcting the spelling of the specific to *murieliae.*[15]

May 1998: Arnold Arboretum plants of *Fargesia murielae,* received from the U.S. National Arboretum in 1960, come into flower for the first time.

PETER DEL TREDICI

The flowers of Fargesia murielae *are inconspicuous*

occurred there during the 1970s—can we hope to obtain material comparable in quality to the original Wilson #1462.

The story of the introduction of Muriel's bamboo is typical of the interplay between meticulousness and confusion that often surrounds the introduction of a new plant. That we can follow the *Fargesia* story as well as we can bears witness to the care and effort that the Arnold Arboretum in general, and Wilson in particular, put into the process of collection and documentation. The story illustrates another point as well: the importance of sharing plants among botanical gardens. Kew Gardens, and especially its horticulturist W. J. Bean, deserve credit for propagating and eventually distributing the plant throughout Europe. Distributing rare plants is an act both of generosity and of self-preservation: if you have two plants and give one away, you can get it back when you lose the one you kept. Such losses happen frequently, but the tradition of sharing plants provides an important safety net that greatly increases the chances of successful introduction. Given the rate at which the forests of the world are disappearing, failure to thoroughly document collections—and to share them—can represent the loss of a resource that can never be recaptured.

Endnotes

[1] S. A. Renvoize, *Thamnocalamus spathaceus* and its hundred-year flowering cycle. *Kew Magazine* (1991) 8(4): 185–194.

[2] E. J. Fortanier and R. H. Jonkers, Juvenility and maturity of plants as influenced by the ontogenetical and physiological aging. *Acta Horticulturae* (1976) 56: 37–44.

[3] G. B. Shaller, J. Hu, W. Pan, and J. Zhu, *The Giant Pandas of Wolong* (Chicago: University of Chicago Press, 1985).

[4] Renvoize, op cit.

[5] D. Jansen, Why bamboos wait so long to flower. *Ann. Rev. Ecol. Syst.* (1976) 7: 347–391.

[6] E. H. Wilson, AA Manuscript #39526: First expedition for Arnold Arboretum; Feb. 1907–Sept. 1909; collecting numbers 1–1474 (undated).

[7] C. S. Sargent, ed., *Plantae Wilsonianae* II (Arnold Arboretum, 1916), 64.

[8] Wilson's diary entry for April 17, 1907, makes no mention of any bamboo, but when I checked the herbarium specimens that document #1462, I found all of them dated "17/5/07" in Wilson's handwriting. In the absence of any journal for the month of May 1907, this discrepancy in dates was resolved by checking Wilson's other herbarium specimens collected at Fang Xian. According to former Arboretum director R. A. Howard, in his 1980 article "E. H. Wilson as Botanist" (part I, *Arnoldia* 40(3): 102–138; part II, 40(4): 154–193), the Fang Xian material all had collection dates in May 1907. This clearly suggests that the date of April 17 published in *Plantae Wilsonianae* is an error, and that May 17, 1907, noted on the specimen, was the actual date for the collection of *Fargesia murielae*.

[9] E. H. Wilson, AA Manuscript #39611: Numerical list of seeds [no. 1–1474, 4000–4462], collected on his Arnold Arboretum expeditions to eastern Asia, 1907–08, 1910, which were planted in the arboretum nurseries (undated, probably 1910–1911).

[10] J. S. Gamble, *in* Anon., *Decades Kewenses: Plantarum novarum in Herbario Horti Regii*

The Arnold Arboretum

F A L L • N E W S • 1 9 9 8

Field Studies Are Inspired by the Work of Volunteers

Diane Syverson
Manager of School Programs

Kirstin Behn

A fourth-grade teacher from the Baker School brought her class to the Arboretum this October for a field study called *Plants in Autumn: How Seeds Travel*. Her response to the question, "What did you like most about your experience at the Arboretum?" was:

> I really admire the fact that this program is staffed by volunteers. I think it's important for kids to see people donating their time and energy because they want to. Additionally the atmosphere was inviting, which made the experience that much better.

Volunteer guides who are personally invested in their work create an invigorating learning environment for school classes that come to the Arboretum for Field Study Experiences. Visiting schoolchildren find themselves in a group facilitated by any one of the 25 men and women who guide children on these fall and spring programs. Each guide is trained to support the children's science learning, as together they examine the plants and habitats within the Arboretum landscape.

As volunteers, the school program guides are dedicated to enriching children's connection with science, nature, and the Arboretum through the Field Study Experience. These volunteers are men and women whose commitment might originate from a personal interest in children's education: they include former teachers, a school librarian, an education graduate student, grandparents, and a person considering a career change to education. Other volunteers come with personal experience and interest in life science: as do a part-time science teacher who saves a day per week to "teach" at the Arboretum, an ex-biology instructor, a retired chemist, a self-employed horticulturist, and many impassioned gardeners. Many of our volunteers know and love the Arboretum from the perspective of neighbor and supporter; it is from this perspective that they invest in sharing its richness with others.

School program guides make a one-year commitment to their job that includes thirty hours of Field Study Experience training; weekly guiding of elementary age children, fall and spring; and attendance at education meetings during the winter months. For more information or to observe a field study program, phone Diane Syverson, manager of school programs, at 617/524-1718 x163.

No Complaints Here

Peter Del Tredici, Director of Living Collections

Gardeners are notorious for their ability to complain endlessly about the weather. If it's not too wet, then it's certainly too dry; if it's not too hot, it's certainly too cold. The right amount of snow is great, but too little or too much is always a problem. And so on down the line. This tendency in

• *continued on page 3*

ELLEN S. BENNETT • EDITOR

Former Intern Returns as Putnam Fellow

Laura Brogna, Putnam Fellow

I've been fortunate, as a child of a foreign service family, to travel in Asia, Europe, and the U.S. and to live in very different kinds of places, including suburban northern Virginia, downtown Tokyo, and the rural Northeast Kingdom of Vermont. Somewhere along the way, noticing my surroundings, I


Karen Madsen

became a student of landscapes and landscape history.

I consider my Putnam fellowship an opportunity to continue my investigations into the workings of New England landscapes, which I began officially as a graduate student in landscape architecture at Harvard's Graduate School of Design (GSD). One of my projects here will be the study of planning and land management issues, including development and tourism pressures on working farms and forests. I also will investigate how the Arboretum functions within its three increasingly urbanized watersheds in order to prepare a stormwater maintenance plan for the site. Finally, I will research the land-use history of the area proposed for a new sun-loving shrub and vine collection.

During my tenure as Putnam Fellow, I am dividing my time between the Institute for Cultural Landscape Studies (ICLS) and the Department of Living Collections. By straddling departments, I am allowed a wonderful balance in my work. I may spend one day devoted to ICLS in the Widener Library stacks at Harvard, tracking down references to farmland conservation or cultural geography. The next day (after studying USGS topographical maps and poring over city wastewater flow diagrams), I'm out following the course of our own Bussey Brook.

I first joined the Arboretum as a horticultural intern in the summer of 1995. After graduating from the GSD in 1997, I spent one year working in a landscape architecture firm before returning to the Arboretum in September of this year. I'm thrilled to be back and feel happily at home here among the trees.

Farewell to Peter Stevens

The imminent departure of Peter Stevens, professor of biology and a curator of the Arnold Arboretum and Gray Herbaria, represents a serious loss to the Arboretum's group of specialists in Asian botany. Peter will be joining his wife, Dr. Elizabeth Kellogg—known to us all as Toby—on the faculty of the University of Missouri at St. Louis. Toby will hold the E. Desmond Lee Chair in Botanical Studies, Peter will be a professor of biology, and both will also hold adjunct positions at the Missouri Botanical Garden.

Peter joined the staff of the Arnold Arboretum as an assistant curator in 1973 after three years as a botanist in the Papua New Guinea Forest Service, and worked his way up through the ranks: quite a feat at Harvard! He has pursued two groups of interests here. One has been in theoretical aspects of the history and practice of systematics, and particularly how botanists use the characters of plants in classification and to interpret evolution. But Peter may well be remembered most for his elegantly crafted systematic treatments, in the St. John's wort family, Clusiaceae, and especially its large and subtly varying tropical tree genus *Calophyllum;* in the rhododendron family, Ericaceae; and in various other taxa that have presented interesting problems to him.

Peter has played a seminal part in the teaching of plant systematics at Harvard. His undergraduate course Bio 103, Evolution and Diversification of Flowering Plants, and his graduate course Bio 218, The Families of Flowering Plants, have attracted a growing number of students who found them dense and therefore difficult but, thanks to Peter's ebullient enthusiasm for his subject, immensely stimulating.

We wish Peter and Toby good success in this new phase in their careers and will welcome their future visits here.

Peter Ashton, Director, 1978–1987

• from page 1

gardeners has only been exacerbated over the course of the last ten or twenty years, as weather extremes become the norm and the so-called hundred-year flood seems to happen once a decade.

All of which takes me to the point of this article, namely, that the living collections department, which has certainly done its share of complaining about the weather in the past, doesn't have anything to complain about this year. The winter was mild and the spring was cool and moist. Remarkably, the summer, which was considered very dry over most of the East Coast, was no problem in Boston where we enjoyed adequate rainfall through the treacherous months of July and August. Indeed, nearly every time we talked about watering our newly installed plants, it started raining. And the same is true for the fall. Two weeks never passed without substantial rain.

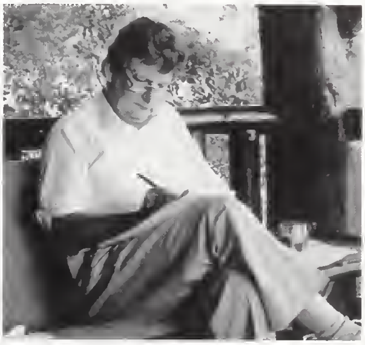
Taking full advantage of this "anomalous" weather pattern, the grounds crew planted more than 120 conifers in the collections from mid-September through mid-October. It was particularly gratifying to plant these trees, given that the Pinetum area was badly damaged by the blizzard of April 1, 1997. While it requires a certain amount of imagination on the part of the visitor, it is now possible to envision the appearance of the Arboretum twenty years into the future, when the new plantings reach adulthood.

This fall's planting list was heavily laden with arborvitae (*Thuja occidentalis* and *T. plicata*), but we also accessioned many pine, fir, larch, and spruce. As it happened, during the long Columbus Day weekend, and just a few days after we planted our last tree, it rained more than four inches in three days, saturating the ground in a way that no amount of hand watering or irrigation ever could. Remarkably, the universal law of compensation seems to have worked its mysterious magic at the Arboretum, making the problems of the past few years seem like distant memories. Unfortunately, I'm sure that next year will be a completely different story.

Dr. Peter Ashton Receives Honorary Medal

On October 15, the Massachusetts Horticultural Society (MHS) awarded Peter Ashton the Thomas Roland Medal of Honor during the MHS Annual Awards Ceremony at the Boston Harbor Hotel. Dr. Ashton served as director of the Arnold Arboretum from 1978 to 1987 and currently is the Charles Bullard Professor of Forestry at Harvard University.

First bestowed in 1927, the Thomas Roland Medal was awarded in recognition of "exceptional skill in horticulture." In presenting the award, Dr. John C. Peterson, president of MHS, lauded Dr. Ashton "for his extensive work that has ensured a wonderful public treasure in Boston's Arnold Arboretum, and for the demonstration of what is without question exemplary skill in the field of horticulture."



John Burley

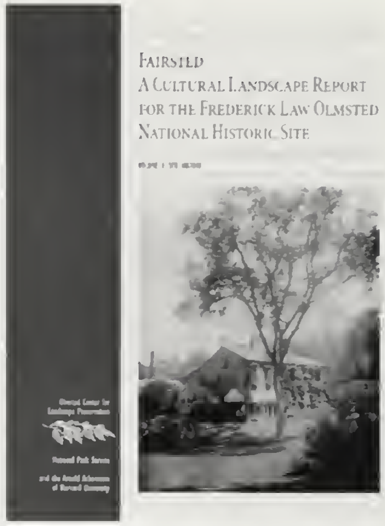
Dr. Peter Ashton, Arnold Arboretum director, 1978-1987

Dr. Ashton's successor as director of the Arnold Arboretum, Dr. Robert Cook, extended the congratulations of the entire staff. "Peter is also the world's foremost authority on the tropical forests of Asia," Cook noted. "We thank Peter for bringing the Arboretum to a position of leadership for conservation of Asian tropical forests."

Karen Madsen

Arnold Arboretum Council members Wendy Pearson, Sarah Jolliffe, and Bob Bartlett prepare to embark on a tour of the living collections following the fall Arboretum Council meeting. Council members serve as advocates for the Arboretum, advise the director in their specialized areas of expertise, and support the institution in a variety of ways. Events of the day included presentations on new initiatives, ongoing projects, and a panel presentation of landscape maintenance issues.

Two Collaborative Projects of the AA/NPS Win ASLA Awards



Both *Fairsted: A Cultural Landscape Report for the Frederick Law Olmsted National Historic Site. Volume 1: Site History* and *Landscape Explorers: Uncovering the Power of Place* won 1998 Merit Awards from the American Society of Landscape Architects (ASLA). Both publications are the result of collaborations between the Arnold Arboretum and the National Park Service that began in the early 1990s.

Fairsted, the Frederick Law Olmsted National Historic Site in Brookline, Massachusetts, was the home and professional office of Frederick Law Olmsted and the subsequent firms headed by his sons and others. The National Park Service acquired the site in 1980. The Fairsted Report, produced jointly by the Olmsted Center for Landscape Preservation of the National Park Service and the Arnold Arboretum, includes a detailed history of the landscape of Fairsted by the noted Olmsted scholar Cynthia Zaitzevsky and an afterword that describes the horticultural and cultural context of the Olmsted's work by the garden historian Mac Griswold. Peter Del Tredici, director of living collections of the Arnold Arboretum, participated in the evaluation of historic documentation of the site and provided valuable expertise in plant identification from historic photographs. This report is an integral part of the restoration process for the Fairsted landscape, which began in 1991.

Although the report documents a site of only 1.76 acres, it is (to quote the ASLA) "a fascinating look at Olmsted's most intimate work: the design, literally, of the master's own backyard." Copies of the report have been distributed to libraries nationwide. Individual copies can be purchased through the Eastern National Bookstore at the Frederick Law Olmsted National Historic Site, 99 Warren Street, Brookline, MA 02446. For mail orders, contact Alan Banks at 617/566-1689 x221.

The ASLA calls *Landscape Explorers* "the first—and thus far—the only curriculum designed to teach elementary-school students about the importance of landscape and place in everyone's lives." This unit of study invites students to explore the landscape from the perspective of an artist, a historian, or a naturalist. The stated hope that drives the unit is that "children who understand the role of 'place' in their evolving sense of self tend to become adults with a commitment to conserving and enhancing their immediate neighborhoods and the larger landscapes of which they are a part." The authors of this work are Diane Syverson, manager of school programs at the Arboretum, and Liza Stearns, education specialist for the Frederick Law Olmsted National Historic Site. Participating students begin their exploration of place by examining their own schoolyard and learning what it means to "read" a landscape. They then apply those newly learned skills in a visit to the Arboretum, exploring this landscape in one of the three distinct ways described above. For further information about *Landscape Explorers*, contact Diane Syverson at 617/524-1718 x163.

PETER DEL TREDICI

Fargesia murielae *at Kew Gardens, lifeless at the conclusion of its flowering in 1997.*

conservatarum. Kew Bulletin of Miscellaneous Information (1920) 10: 344–345.

[11] Perhaps Wilson used 1910 as the date for "successfully" introducing *Fargesia murielae* because it was then that he inventoried his collections for those that were actually alive "in the arboretum nurseries." An alternative, and rather unlikely, interpretation is that Wilson recollected the bamboo in 1910 and simply recycled #1462 from the 1907 expedition. Of course, one can not discount the possibility that Wilson just made a mistake in giving 1910 as the date for the introduction of *F. murielae.*

[12] At the National Arboretum the plant was given inventory number 262266; at the Arnold Arboretum, it became accession number 1239-60.

[13] T. R. Soderstrom, The Bamboozling *Thamnocalamus. Garden* (1979) 3(4): 22–27; Renvoize, op. cit.

[14] M. A. Franchet, *Fargesia, nouveau genre de Bambusées de la Chine. Bull. Mens. Soc. Linn.* (Paris, 1893) 2: 1067–1069.

[15] C. Stapleton, Muriel Wilson's Bamboo. *Newsletter of the Bamboo Society* (*European Bamboo Society*, Great Britain, January 1995), 21.

Acknowledgments

The author would like to express his thanks to Dr. Chris Stapleton, consulting taxonomist at Kew Gardens, for his help in sorting out the complex history of the introduction of *Fargesia murielae*, and to Keiko Satoh, Putnam Research Fellow at the Arnold Arboretum, for help in sifting through the Wilson Archives, housed at the Arnold Arboretum.

Peter Del Tredici is Director of Living Collections at the Arnold Arboretum.

Nature Study Moves into the Twenty-First Century

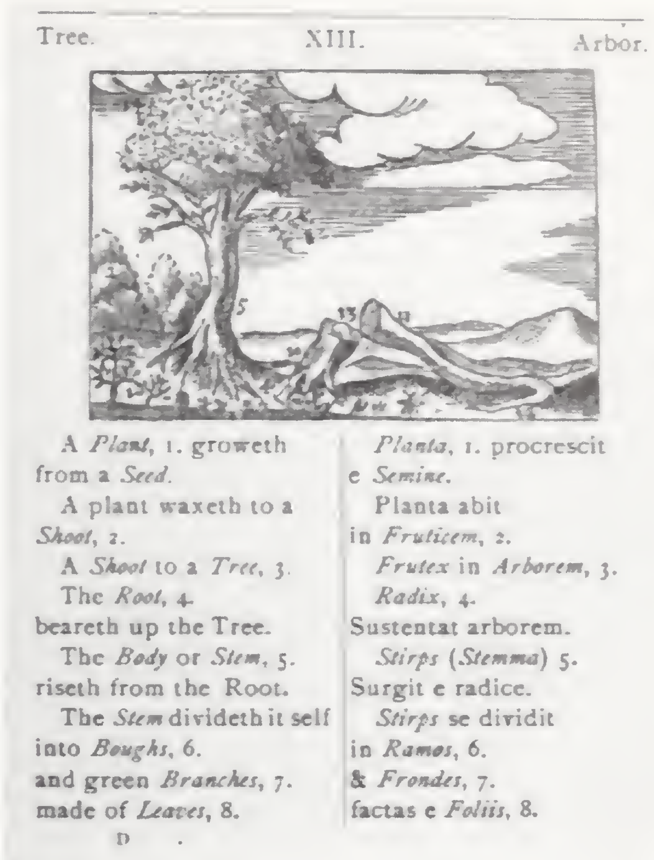
Candace L. Julyan

The veining of the leaves and the construction of the stalks . . . are as interesting to me as the construction of a locomotive is to an engineer. When you get to know the plants, you feel as though you ought to have a garden where you can take care of real plants and study them.

Plants move, though many people do not know it. It is true that they do not move with a jerk, but they move very slowly. When the corn gets beaten down by a heavy rain or hail storm, it gradually works itself up again, although it never gets perfectly straight as before. When we move, we bend our joints. That is the way also with the corn. It bends at the nodes.

——*Reports from fourth-grade students at the Francis Parker School, Chicago, 1915.*[1]

In many respects these reports could be more readily attributed to students today than to those at the beginning of this century. The study of plants is now considered a routine part of the elementary curriculum, and reports are a standard form of communication between teacher and student. However, classroom practice that encourages students' observations of nature, considered laudable today, was much more controversial at the beginning of the century. At the Arnold Arboretum, education for children has been shaped by our strong belief that the most powerful learning happens out in the landscape, a belief that was articulated at the turn of the century by participants in the "nature-study movement." The fourth-graders quoted above, students at a school founded on the principles of this movement, had studied plants by observing corn growing in their schoolyard, rather than by reading about it in a textbook. A closer


Tree. XIII. Arbor.

A *Plant*, 1. groweth from a *Seed*.	*Planta*, 1. procrescit e *Semine*.
A plant waxeth to a *Shoot*, 2.	Planta abit in *Fruticem*, 2.
A *Shoot* to a *Tree*, 3.	*Frutex* in *Arborem*, 3.
The *Root*, 4. beareth up the Tree.	*Radix*, 4. Sustentat arborem.
The *Body* or *Stem*, 5. riseth from the Root.	*Stirps* (*Stemma*) 5. Surgit e radice.
The *Stem* divideth it self into *Boughs*, 6.	*Stirps* se dividit in *Ramos*, 6.
and green *Branches*, 7. made of *Leaves*, 8.	& *Frondes*, 7. factas e *Foliis*, 8.

D

SPECIAL COLLECTIONS, MUNROE C GUTMAN LIBRARY OF HARVARD UNIVERSITY GRADUATE SCHOOL OF EDUCATION

look at the tenets of nature-study serves to identify the roots of our beliefs and to illuminate new ways to approach the study of nature.

The nature-study movement, which peaked between 1890 to 1920, was part of a progressive education philosophy that proposed a child-centered approach to learning by encouraging engagement and play in contrast to more traditional, text-driven practices. Nature-study educators (who used the hyphen to signify that their nature study included a pedagogical approach) proposed that learning about the natural world was as important as studies of reading, writing, arithmetic, and grammar. The key precepts of the nature-study movement can be summarized briefly:

- The objects of study can be ordinary, seasonal phenomena.
- Direct observation is central to learning; drawing can be a useful, complementary tool.
- The teacher guides the students' exploration; fostering discussions is considered more critical than memorization.
- Truly significant learning about nature takes place outdoors, "in nature."
- Education should instill a love of nature in the child.[2]

Much of the impetus for this movement came from a concern that the rigid approach to teaching was not resulting in significant learning by students. Samuel Jackson, an important spokesman for the movement, summarized the dissatisfaction of many with traditional book-centered study:

> Instead of providing the child with proper conditions which cause him to grow out of the old into the new, usually, the teacher *merely smites him with a definition.* The child is finally belabored into *saying,* "The earth is round like a globe or a ball," and the matter is dropped; but most of his geography forever conforms to his picture of the old *flat* earth of his childhood.[3]

Such misgivings were certainly not new. Over two centuries earlier, the Moravian monk John Amos Comenius (1592–1670) wrote a critique of the approach to children's education at that time:

> Hitherto the schools have done nothing with the view of developing children, like young trees, from the growing impulse of their own roots, but only with that of hanging them over with twigs broken off elsewhere. They teach youth to adorn themselves with others' feathers, like the crow in Aesop's Fables. They do not show them things as they are, but tell them what one and another, and a third and a tenth, had thought and written about them, so that it is considered a mark of great wisdom for a man to know a great many opinions which contradict each other.[4]

Comenius developed his ideas in the first illustrated children's book, *Orbis Pictus*, published in 1658 and focused on topics familiar to young people. The book's small woodcut graphics are accompanied by short texts that deal with a wide range of topics drawn from both nature and ethics—from clouds, trees, and animals, to honesty, respect, and love.

Another writer influential in the development of the nature-study movement was Jean Jacques Rousseau (1712–1778). Many of his ideas were incorporated into the movement's philosophy: the principles of science are discovered by the child, not learned as facts; learning should begin with observation of common phenomena; the order of learning should be determined by the learner's interests and experiences, not by the organization of science; and the objective should be enthusiasm for the discipline and methods of science, rather than a body of memorized facts.[5]

As the nature-study movement gathered momentum in the late nineteenth century, its leaders built upon these ideas to create an approach to education with careful study of the outdoor environment as its centerpiece. While a growing number of teachers found these ideas exciting and in line with their own thinking, many others were baffled by the idea of teaching without books and using natural objects and phenomena to help children understand the world around them. Ultimately the movement lost strength as educators turned away from the ideas of progressive education in favor of more traditional approaches.

The Relevance of Nature-Study Today

While the philosophy of the nature-study movement could be found in small pockets of schools throughout this century, the ideas gained favor again in the 1960s and 1970s with the growth of environmental education and of science education that focused on experience and, more recently, in the 1980s and 1990s, with a renewed focus on science education. The notion of a compatibility between science and nature-study was not prevalent at the turn of the century. Although exceptions existed, such as Louis Agassiz, a nineteenth-century scientist whose credo was "Study nature, not books," generally, nature-study educators and professors of science held significantly different ideas, as suggested in these passages written by Anna Comstock in 1911:

> For a long time botanical science, in the popular mind, consisted chiefly of pulling flowers to pieces and finding their Latin names by the use of the analytical key. All the careful descriptions of the habits of plants in the classic books were viewed solely as conducive to accuracy in placing the proper label on herbarium specimens. Long after the study of botany in the universities had become biological rather than purely systematic, the old regime held sway in our secondary schools; and perhaps some of us today know of high schools still working in the first ray that pierced primeval darkness. . . .
>
> To-day nature-study and science, while they may deal with the same objects, view them from opposite standpoints. . . . The child, through nature-study, learns to know the life history of the violet growing in his own dooryard, and the fascinating story of the robin nesting in the cornice of his own porch.[6]

Comstock explained that nature-study "does not start out with the classification given in books, but in the end it builds up a classification in the child's mind which is based on fundamental knowledge; it is a classification like that evolved by the first naturalists, it is built on careful personal observations of both form and life."[7]

She would, no doubt, be surprised to learn how the teaching of science has shifted in the intervening years. In 1994, the National Academy of Science convened a large group of scientists and educators to consider how and what children should learn about science and the environment. The conclusions of this group, published in 1996 as the *National Science Education Standards* (NSES), suggest certain "big ideas" to be addressed at each grade level and propose an approach to teaching that in many ways resembles the one endorsed by the nature-study authors at the turn of the century:

> Learning science is something students do, not something that is done to them. In learning science, students describe objects and events, ask questions, acquire knowledge, construct explanations of natural phenomena, test those explanations in many different ways, and communicate their ideas to others.[8]

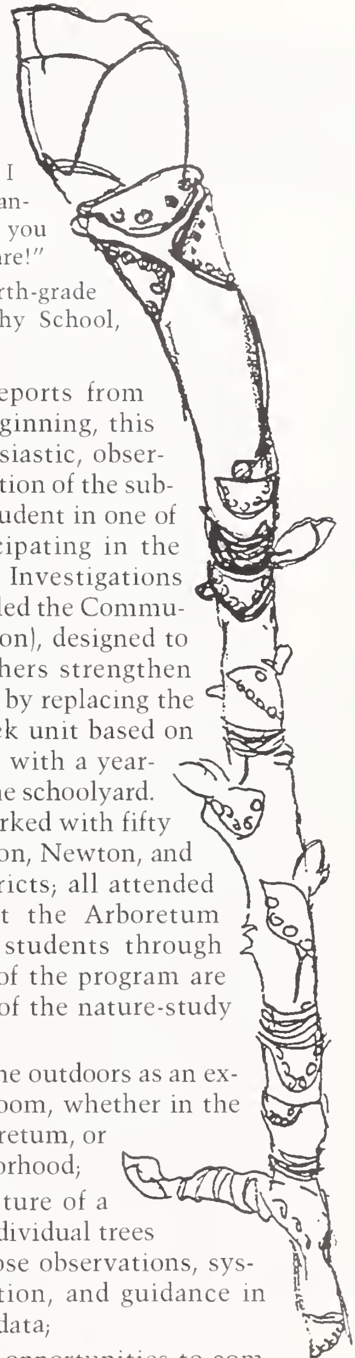
The Arboretum's work with children employs a combination of the nature-study philosophy and scientific practice. Begun in 1984, the Arboretum's Field Studies Experiences are designed for small groups of elementary stu-

dents who come to the Arboretum to observe closely and make sense of what they see. In the fall, students look for seeds and determine their mode of travel; in the spring, they discover the stages of transformation from flower to fruit. In both of these activities, careful observation is supplemented by conversations with the guides, who help students make sense of what they see. This program is based on a belief that children learn best through experiences in the landscape, guided by attentive adults.

A decade later, we explored ways to add data collection to these observation-based activities. In 1995, with funding from the National Science Foundation (NSF), the Arboretum began the development of a program that could serve as a model for partnerships between elementary schools and institutions involved in science. While based on many of the principles of nature-study, this new project, called Seasonal Investigations, also includes an emphasis on keeping systematic records of observations and sharing those data with others using a computer web site.

A Design for Nature Study in the Twenty-First Century

> Before I investigated a twig in winter, I just thought that the leaves fell off a tree and gradually grew back. But boy, did I learn a lot about trees from just one little twig!
>
> Maybe I should tell you about some things I learned. . . . I learned the names of the different parts of a twig, like the Terminal Bud, which is the bud at the tip, and the Lateral Buds, the little buds on the sides. I, myself, liked the names our class made up better. Like the name I gave to the Terminal Bud, Kiss-End Tail (an off-spring from the expression "Kiss and Tell").
>
> Another thing I learned from my twig is that the different colors along the twig signal yearly growth. We also determined the yearly growth for 1995–96 by looking at the first ring from the top. Then we measured from that ring to the very tip of the twig. Get this, my twig grows one centimeter less each year! So next year, if my twig only grew one centimeter since 1995, my twig will probably stop growing. Or maybe it will start a whole new growth. I think that the reason my twig's health has been declining is because of the harsh winters we've been having. Well it'll sure be a big surprise [this spring]!
>
> My twig was a very informative source. I learned more about trees than I could ever fit into one report. So I better go before I start another paragraph telling you about how great trees are!"
>
> —Report from a fourth-grade student at the Murphy School, Boston, 1996.

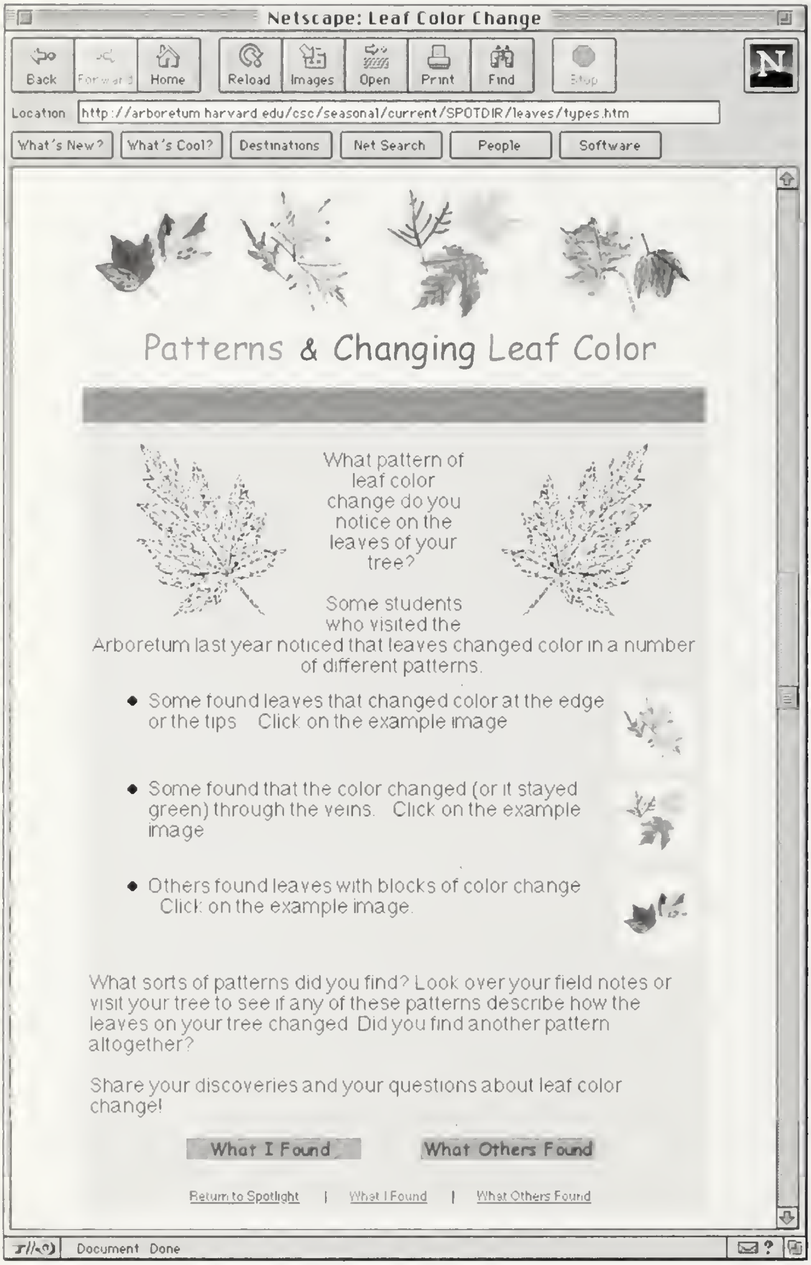


Like the student reports from 1915 quoted at the beginning, this one displays an enthusiastic, observation-based consideration of the subject. The author is a student in one of the classrooms participating in the Arboretum's Seasonal Investigations program (originally called the Community Science Connection), designed to help elementary teachers strengthen their science curricula by replacing the usual one- to two-week unit based on textbook explanations with a year-long study of trees in the schoolyard.

To date, we have worked with fifty teachers from the Boston, Newton, and Brookline school districts; all attended summer institutes at the Arboretum before guiding their students through the study. The goals of the program are very similar to those of the nature-study movement:

- to encourage use of the outdoors as an extension of the classroom, whether in the schoolyard, the Arboretum, or the students' neighborhood;
- to provide the structure of a year-long study of individual trees that incorporates close observations, systematic data collection, and guidance in making sense of the data;
- to give the students opportunities to communicate on the web with others studying the same topic.

The program proceeds through three seasons. The fall investigation focuses on the general characteristics of trees and on the ways species differ, such as in the dates that leaves change



color and fall from the tree. In the winter investigation, students learn to "read" a twig and use their new knowledge to determine which was the best recent growing year for the schoolyard trees. The spring investigation revisits the features examined in the winter to learn whether and how those features change in the spring and to determine when the flowers are "open for business."

The student report quoted above was written as part of the winter twig investigation. The twigs, initially viewed by students as a bag of sticks, constitute the major focus of the class investigation. Each twig soon becomes a treasured resource. Students begin by making careful drawings and identifying features of the twig, later naming the features. These names are often revealing. For example, one student named the annual growth-ring marks "growing up lines." Many students preferred their own names to those of scientists, but they were fluent in both.

The Role of the Web Site

Now in our final year of NSF funding, we are designing a web site for Seasonal Investigations that we believe will support both the classroom and outdoor work and allow a greater number of teachers to take part in the project. While the program can be (and sometimes is) completed successfully using only the classroom and schoolyard, the on-line environment provides an important support for the four activities central to the project—observation, data collection, communication, and publication—with a web site feature dedicated to each of these activities.

The Spotlight feature changes weekly throughout each seasonal investigation; the topic of each entry is chosen to encourage closer observation. In the fall investigation, students were invited to consider patterns of leaf change, to view other students' drawings of patterns they found, and to share their observations about leaf patterns with others. Another Spotlight entry asked them to consider how bark accommodates the expansion of a tree's girth. Three possibilities—fissures, plates, and peels—were illustrated with photos; students were

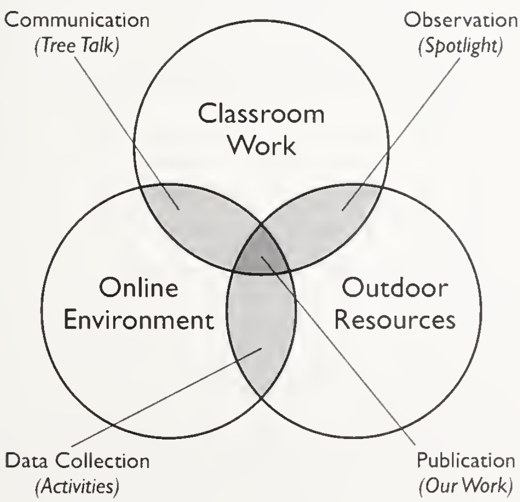
asked to look at their schoolyard trees and report their findings.

The Tree Talk feature facilitates communication among classes, from initial letters of introduction to later conversations about questions or findings. Contributions to most of these "conversations" can be made and viewed at any time; in addition, there is an option for a live, scheduled chat with either Arboretum staff or other classrooms.

The Activities feature provides the structure for sharing data among classes. Students are asked to provide specific data about their schoolyard trees, changing or adding to the data as the study progresses. The combined data provide opportunities for discussion in the classroom or with other students.

The Publication feature is intended to elicit a creative activity at the end of each investigation, perhaps a report or drawing, that brings together the ideas, surprises, and discoveries from the investigation.

The first three years of the project were spent perfecting the model and developing a set of investigations that could be completed in the schoolyard, with supporting visits to the Arboretum. During this, the last year of the project, the focus is on perfecting the web site to ensure that the program will continue after NSF funding ends.



Even before the project's completion, the framework of Seasonal Investigations has been adopted as a model by other institutions engaged in science education. Descanso Gardens in Los Angeles is replicating the entire program as a pilot project with the Los Angeles Unified School District. The Garden's director, Richard Schulhof, had first-hand experience with the project as a member of the Arboretum staff at the time it began, and is enthusiastic about using the program as a new approach to science teaching for his own staff as well as for the Los Angeles teachers. In addition, the Massachusetts Audubon Society is using the Seasonal Investigations framework to develop both teacher institutes and investigations of vernal pools in three locations across Massachusetts.

Future Directions

Many of the ideas of the nature-study movement are alive and in practice in today's programs at the Arboretum, but new issues

are also being raised. What role can the web play, not as an end in itself but as a springboard to investigations outdoors? How might it provide an avenue for sharing our educational ideas, many of which have century-old roots, with interested educators around the globe?

In many ways, the words of Anna Comstock have as much relevance at the end of this century as they did at the beginning:

> When the child has become acquainted with the conditions and necessities of plant life, how different will the world seem to him! Every glance at forest or field will tell him a new story. Every square foot of sod will be revealed to him as a battlefield in which he himself may count the victories in the struggle for existence, and he will walk henceforth in a world of miracle and of beauty,—the miracle of adjustment to circumstances, and the beauty of obedience to law."[9]

The young author who wrote about her twig is one of a growing number of students whose science experiences have been shaped, either directly or indirectly, through a connection with the Arboretum and its staff. As we enter the twenty-first century, we continue to seek opportunities for sharing our ideas about the compatibility of nature, science, and technology with teachers and students eager to learn about trees and plants. Our hope is that ideas about children's education, developed and nurtured at the Arboretum, can grow into viable "seeds" locally and around the country.

Endnotes

[1] From the Francis Parker School Year Book, vol. IV, June 1915 (Archives of Gutman Library, Harvard University).

[2] Culled from W. S. Jackman, *Nature-Study and Related Subjects for Common School.* Part II. (New York: Henry Holt, 1891); A. C. Boyden, *Nature Study by Months* (Boston: New England Publishing, 1898); G. L. Clapp, "Real and sham observation by pupils," *Education*, January 1892; C. B. Scott, *Nature-Study and the Child* (Boston: D. C. Heath, 1901); A. B. Comstock, *Handbook of Nature-Study* (Ithaca, NY: Comstock Publishing, 1911).

[3] Quoted in Jackman, op. cit., pp. 9–10.

[4] Quoted in N. A. Calings, "History of Object Teaching," *Barnard's American Journal of Education* (December, 1962) 12: 637.

[5] Quoted in T. Minton, "The History of the Nature-Study Movement and Its Role in the Development of Environmental Education" (Unpublished dissertation, University of Massachusetts, Amherst, 1979), pp. 30–31.

[6] Quoted in G. F. Atkinson, *First Studies of Plant Life* (Boston: Ginn & Co., 1901), p. iii.

[7] Comstock, op. cit., p.5.

[8] National Research Council, *National Science Education Standards* (Washington, D.C.: National Academy Press, 1996), p. 20.

[9] Atkinson, op. cit., p. v.

Candace Julyan is Director of Education at the Arnold Arboretum.

Native vs. Nonnative: A Reprise

Letters to the Editor

To the Editor:

I thoroughly enjoyed the article "An Evolutionary Perspective on Strengths, Fallacies, and Confusions in the Concept of Native Plants" by Stephen Jay Gould (*Arnoldia* Spring 1998). Gould uses the native plant issue to clarify some of the common misconceptions surrounding the basic theory of natural selection. He also reasserts himself as one of Darwin' prevailing "bulldogs." I do not take issue with anything that Gould includes in his analysis, but rather what he *fails* to include. Little effort is made to address the evolutionary *ecology* perspective in the concept of native plants.

Gould touches lightly on the merits of native plants by indicating that they "have generally been present for a long time and have therefore stabilized and adapted" to local conditions. This is for me a key reason, from an evolutionary perspective, for promoting native plants, since natives have presumably coevolved with other local organisms and the chemical and physical environment. An ecological balance has, therefore, generally been struck that prevents the unbridled increase in any one species' numbers. Exotic plant species (i.e., nonnative plants), on the other hand, have a greater propensity for rampant population growth. Darwin even comments on the ecological consequences of invasive exotic plant species and points out in chapter three of *On the Origin of Species* that:

> . . . cases could be given of introduced plants which have become common throughout whole islands in a period of less than ten years. Several of the plants now most numerous over the wide plains of La Plata, clothing square leagues of surface almost to the exclusion of all other plants, have been introduced from Europe. . . . In such cases the geometrical ratio of increase, the result of which never fails to be surprising, simply explains the extraordinarily rapid increase and wide diffusion of naturalized productions in their new homes. . . . when a plant or animal is placed in a new country amongst new competitors, though the climate may be exactly the same as in its former home, yet the conditions of its life will generally be changed in an essential manner.

Irruptions of invasive exotic plant and animal species typically occur, as Darwin implies, because they do not generally have the competitor, predator, or pathogen load typically associated with native plants. Exotic species are new players in an environment and do not adhere to the "rules" that govern native species. Admittedly, the vast majority of exotic species are not invasive since they do not seem to compete well with native plants. Those that are invasive, however, have wrought havoc on local and regional ecosystems. Many native plants are maligned as invasive because of their weedy nature, but there is a distinct difference: native weeds do not disrupt natural communities nor do they tend to form monocultures. (I would like to

PETER DEL TREDICI

see the term "invasive" restricted to ecologically disruptive exotic plants and the term "aggressive" adapted for native weeds.)

Gould also gives little mention to the ecologically disruptive consequences of invasive exotics to biodiversity other than saying that he "treasures nature's bounteous diversity of species," and that "cherishing native plants does allow us to defend and preserve a maximal amount of local variety." This is precisely why native plants should be the first choice for landscaping among ecologically sensitive individuals. Second choice should be exotic species that are not invasive or those that have a very low potential for becoming invasive. I am not suggesting that we adopt the "Naziesque" approach to plant material choice. I too am awed by our "bounteous" species diversity but it is only *diminished* by invasive exotic species. And I hope that Gould, by pointing out that the argument for using native plants is evolutionarily fallacious, has not encouraged what he so stridently abhors: a misconstrued Darwinian alibi for depraved behavior—in this case, using ecologically disruptive, invasive plant species.

Organisms, native or otherwise, respond to their environment through the adaptive creativity of natural selection. Theirs is a life without intent. There is no desire among plants to become a garden pest or to disrupt natural communities. Humans, by purposefully homogenizing the world's flora, have forced the occurrence of unlikely species interactions, some of which we greet with delight (culinary herbs, vegetable crops, and the majority of ornamentals) and some with dread (kudzu, privet, and water hyacinth). Gould weakly dissuades the introduction of invasive exotic plant species by maintaining that there should be "sensitive and respectful mixing of natives and exotics." From this I read: proceed with caution. I feel that a stronger position needs to be taken on this issue. Invasive exotics are a major threat to biodiversity and the genetic diversity contained within. I therefore challenge botanical gardens and arboreta, plant nurseries, and private gardeners to promote the use of ecologically judicious plant choices in our public and private gardens.

John Randall
Conservation Curator, North Carolina Botanical Garden of the University of North Carolina at Chapel Hill

---

To the Editor:

Stephen Jay Gould ("An Evolutionary Perspective on Strengths, Fallacies, and Confusions in the Concept of Native Plants," *Arnoldia* Spring 1998) offers an excellent argument for his characterization of the concept of native plants as "a remarkable mixture of sound biology, invalid ideas, false extensions, ethical implications, and

Grapevines (Vitus *sp.*) *in northeastern Connecticut.*

political usages." It seems worth adding to his commentary, written from an evolutionary perspective, an argument from the perspective of practical horticulture.

But first, I hasten to point out that in 1998, we in the arenas of botanic gardens and horticulture are already working to promote the use of environmentally appropriate plants specific to the requirements and use of the planted site. Plantsmen are not recommending aggressive exotics as landscape plants of preference regardless of environmental consequences. That would not only be irresponsible but would ultimately destroy the green industry and its important contribution to the U.S. economy.

The primary criteria for plant selection in managed environments today is whether a plant is reasonably well adapted to the site and, hence, will survive and thrive without requiring regular use of pesticides, and within that context, whether the plant satisfies the ornamental, agricultural, and/or functional demands of the site and its constituents. Given these criteria, there are many instances when exotic plants are the clear choice for a given landscape—especially when we recall that not all exotics are invasive or aggressive (in fact only a small minority have proven to be so), and that not all natives are nonaggressive (for instance, our native staghorn sumac). The real challenge, of course, is to determine with intelligence and sensitivity to site constraints what are the environmentally appropriate species for a given site that are likely to succeed there. And, I might add, what may be the appropriate cultivars, which are capable of great phenotypic and physiological divergence within one species—in some cases, even greater divergence than the wild-type species can offer within a genus.

We cannot ignore the reason that invasive exotics have been used in the first place, which is: Managed environments (cities, residential neighborhoods, parks, disturbed wetlands, timber production lands, and so on) are already drastically altered and have already been interfered with, resulting in significantly inhibited natural selection and the ability of the prior extant site natives to thrive. For this very reason, a managed environment often requires conscious choice of potentially aggressive plants if there are to be any plants at all that live there.

One of the reasons that botanic gardens, arboreta, and many types of public gardens maintain living collections of plants is to allow for evaluation and comparison of plant growth and development, and landscape performance long-term in real time in a given regional landscape. The ability to carry out these evaluations allows us to select well-adapted plants for an area. The broader the palette of well-adapted plants available, the more effectively an environmentally sound landscape can be built.

All sites, whether managed or wild, including severely disturbed and altered stressful environments (such as urban parks), require plants adapted to the conditions on that site. A well-adapted plant for a managed site may or may not be a regional native, depending on the specific stresses associated with the given managed environment. We cannot effectively plant many of the natives of the humid Northeast United States in, for example, parking lot beds, or even in many new suburban garden sites that have been stripped of topsoil (excepting only such broadly adapted and aggressive natives as, for instance, poison ivy).

Many Asian natives serve as good landscape plants in the Northeast precisely because they are well-adapted to our most common types of "disturbed" landscapes. The climatic and soil similarities between eastern North America and eastern Asia are well documented and widely understood and accepted. Should we, in spite of this natural botanical gift, restrict the plants grown on these sites to a few U.S. natives that will thrive there because they will basically thrive anywhere? Do we want our managed outdoor stressful environments to be planted with only a limited palette of regionally native aggressive plants? Would the residents of Washington, D.C., really want us to replace the flowering Asian cherries with native pin cherries (which are actually more susceptible to tent caterpillars)?

How do we define "regionally native," in any case?—plants found growing within a 100-mile radius of the site now, 100 years ago, 1000 years ago? Plants found growing within the state now, 50 years ago, 100 years ago? Plants found growing within the region now, 50 years ago, 100 years ago, 1000 years ago?

Much as we may wish to, we cannot turn back the clock and erase the huge disturbances that we have thoughtlessly imposed throughout most of our native habitat. This makes it even more critical that we preserve and protect what small acreages of undisturbed habitat remain, as much as is possible.

Unfortunately, with increasing population and urbanization, the likelihood is that over the next 100 years, these small acreages of undisturbed, or little-disturbed, or restored habitat will become even more fragmented, pressured, and fragile. It is imperative that we learn to manage our expanding areas of managed environments wisely, using a diversity of plants that result in environmentally sound as well as beautiful, productive, and functional landscapes. We cannot achieve that goal by relying solely on "regionally native" plants for every single managed landscape no matter its location or purpose.

Clearly, a reasonable, moderate, thoughtful, site-specific, and non-arbitrary approach to plant selection is required for each individual landscape. Known rampant invasives, regardless of provenance, should not be planted. The decision process for what plants to include in a native wetland restoration project should clearly be drastically different from that of choosing plants for an urban pocket park. In all cases, effort to use plants suited to the region and the site must be made.

I write this response to remind us of what we all as plantsmen are already working to achieve, that is, to bring reason, responsibility, knowledge, and moderation to bear on the process of how we choose plants for managed environments, and what choices we make. In the face of the next hundred years of increasing pressure on the land, the future of our flora and the quality of our lives depends on this.

Kim Tripp
Director of the Botanic Garden of Smith College
and Arnold Arboretum Associate

Native Plants: Another View

Harrison L. Flint

To close this circle, for the time being, we reprint very nearly verbatim an article from *Arnoldia*, Winter 1982–1983. When we asked Professor Flint to update it to serve as a companion to the letters to the editor, he found very little, and nothing at all of substance, that he wished to change.

Following the tradition of such great midwestern naturalists as Jens Jensen, Aldo Leopold, and May Theilgaard Watts, contemporary landscape planners have grown in awareness of native plants and their usefulness in designed landscapes. The movement toward landscaping with native plants now has spread widely and has not yet reached its full potential. Its ultimate expression is found in re-creating natural plant communities, a stepwise and time-consuming process now being carried out by relatively few landscape planners. Such planners usually are sophisticated horticulturists and landscape architects who have elected to specialize in this particular area.

Yet, while many landscape planners have developed close familiarity with a great range of plants, carefully selecting those most appropriate for the situation at hand, less-sophisticated members of their profession have eschewed all forms of vegetation that are not "native." For some this position is taken with a sense of missionary zeal; for others it may simply offer convenience in requiring knowledge of a smaller number of landscape plants.

To select landscape plants on the basis of whether or not they are native, one must first determine which species are "native." In New England, for instance, is it permissible to select black locust *(Robinia pseudoacacia)*, a common wild tree in much of the area, yet native only farther south and west? Must redbud *(Cercis canadensis)* be excluded in southwestern Wisconsin, since it is an exotic species in that state, even though it grows naturally a dozen miles away in northwestern Illinois? In Indiana, must another tree legume, American yellowwood *(Cladrastis kentukea*, formerly *C. lutea)*, be restricted in use to only those few counties where it is indigenous?

Any question about species eligibility for use in re-creating or preserving a natural plant association finds its answer in the planner's knowledge of the association. Clearly, only certain plants "belong." But in other areas of landscape planning, divisions between native and nonnative species blur—and perhaps are best left blurred, allowing selection decisions to be made according to criteria relating to function.

Exclusion of nonnative plants on principle is based upon several generalized claims, all of which hold at least a grain of truth:

(1) Nonnative plants look out of place in the landscape.

If one's objective is to preserve a natural landscape, ample justification exists for removing nonnative species as weeds. The same is true in re-creating a "natural" landscape, but in other cases the question is not so easily answered. Must a woodland gardener in New England be asked to plant no other species of wild ginger *(Asarum)* than the native *A. canadense*? Must sweetshrub *(Calycanthus floridus)*, galax *(Galax urceolata)*, box huckleberry *(Gaylussacia brachycera)*, and yellowroot *(Xanthorhiza simplicissima)* be left to their more southerly native haunts? And must the New England gardener be sure to omit lily-of-the-valley *(Convallaris majalis)* and English ivy *(Hedera helix)* as European natives? Perhaps, but only as a matter of taste.

(2) Plant species are better adapted to the region in which they are native than

elsewhere, because this region has "made" them, through distinctive selection pressures.

As logical as this view may seem at first, it has two flaws. First, it excludes the possibility of preadaptation. For example, the climate of northeastern Asia so closely parallels that of similar latitudes in northeastern North America that many Asian species have been preadapted to our climate long before they have seen it, and turn out to be some of our most useful landscape plants.

A second flaw is the tacit presumption that the soil and climate of a particular landscape site are similar to those of the natural region in which it is located. Landscape designers and contractors know that this is not true. Most landscape sites, especially urban ones, are exposed to soil and climatic stresses that seldom exist in wild areas nearby. Soils may be greatly modified by construction and subsequent restoration. Patterns of wind, solar radiation, and temperature fluctuation are modified in developed sites. Perhaps most important of all, patterns of rainfall, runoff, and absorption of water into the soil are drastically altered. In short, developed sites are so greatly changed that they may differ much more from nearby natural areas than do certain natural areas on the other side of the earth.

(3) Nonnative plants are weedy, reproducing freely and invading areas where they are not wanted.

This is a valid criticism of several nonnative species, such as buckthorns (*Rhamnus* sp.), certain Asian honeysuckles (*Lonicera* sp.), kudzu vine *(Pueraria lobata)*, some species of *Elaeagnus, Euonymus*, and others. But it is not a fair generalization. In fact, it seems a contradiction to generalize that nonnative species are not well adapted yet reproduce to the point of being a nuisance. Again, it is necessary to know which species, both native and exotic, are weedy and exclude them in situations in which they might get out of control.

(4) Native plants are less susceptible to insect and disease problems than nonnatives and so need less maintenance.

We as often hear the counterclaim: that nonnative plants separated from their ecosystems are, at least for a time, free of many of their natural enemies, and examples of native species with major problems are easily found. American elm *(Ulmus americana)* has been decimated in many areas by Dutch elm disease and phloem necrosis. The most promising sources of resistance to Dutch elm disease are Asian species and their hybrids. The majestic American chestnut *(Castanea dentata)*, nearly wiped out by blight in its native habitat decades ago, is finding its closest replacement in the disease-resistant Chinese chestnut *(C. mollissima)* and its hybrids.

Crabapples native to eastern North America (e.g., *Malus angustifolia, M. coronaria*, and *M. ioensis*) are susceptible to cedar-apple rust, a serious enough problem to rule them out as landscape plants in most localities where red cedar *(Juniperus virginiana)*, the alternate host for the disease organism, is present. Asian crabapples are relatively free of this problem. In areas where red cedar does not grow wild, the disease can be largely controlled by substituting junipers of Asian origin for red cedar.

Resistance to insect and disease problems is too important a consideration in selecting landscape plants to be left to generalization. It is better dealt with directly by selecting troublefree plants than indirectly by selecting only native or nonnative plants, in the expectation that they will tend to be more resistant to problems than their opposite numbers.

(5) We need to make better use of the tremendous pool of genetic diversity inherent in native plant species, a pool that has been barely sampled thus far.

Amen! And the same can be said for nonnative species. How often is our knowledge of an Asian species, for instance, limited to a few clones or at best a narrow slice of the germplasm that exists in the natural range? Intrepid plant explorers have introduced to us many new species from remote corners of the world. Notwithstanding the many collections made over the past decade, we have largely failed to follow up on their discoveries by assembling larger samples of those species for evaluation, just as surely as we have neglected to observe fully the variation that exists in native species. As a

result, our narrow knowledge of diversity in plant species confounds the issue of their nativeness.

The U.S. Department of Agriculture has taken an important step to improve this situation with regard to crop species through its network of plant germplasm repositories. It is up to other institutions, including botanical gardens and arboreta, to develop stronger programs relating to preservation and development of germplasm of value to landscape improvement.

There are, of course, landscape situations where nonnative plants are clearly inappropriate and so to be avoided. This includes preservation, restoration, and re-creation of natural areas and plant associations. In many other situations the constraint of using only native plants, intended to produce a natural effect, itself becomes artifact. In such situations it is more sensible to return to the basics of plant selection, considering adaptability and intended function first, then maintenance requirements and seasonal interest. When a pool of plants having the desired requirements has been assembled, final selections can be made on the basis of individual taste.

The search for a broad range of prospective landscape plants, and their thoughtful use, has made our landscape increasingly functional and interesting. Continuing the search will enrich our lives in the process.

Harrison Flint is professor emeritus of horticulture at Purdue University in Lafayette, Indiana. He is the author of *The Country Journal Book of Trees and Shrubs* and *Landscape Plants for Eastern North America*, 2nd edition.

U.S. POSTAL SERVICE
STATEMENT OF OWNERSHIP, MANAGEMENT, AND CIRCULATION
(Required by 39 U.S.C. 3685)

1. Publication Title: *Arnoldia*. 2. Publication No: 0004–2633. 3. Filing Date: 12 November 1998. 4. Issue Frequency: Quarterly. 5. No of Issues Published Annually: 4. 6. Annual Subscription Price: $20.00 domestic; $25.00 foreign. 7. Complete Mailing Address of Known Office of Publication: Arnold Arboretum, 125 Arborway, Jamaica Plain, Suffolk County, MA 02130–3500. 8. Complete Mailing Address of Headquarters of General Business Office of Publisher: Arnold Arboretum, 125 Arborway, Jamaica Plain, Suffolk County, MA 02130–3500. 9. Full Names and Complete Mailing Address of Publisher, Editor, and Managing Editor: Arnold Arboretum, 125 Arborway, Jamaica Plain, Suffolk County, MA 02130–3500, publisher; Karen Madsen, Arnold Arboretum, 125 Arborway, Jamaica Plain, MA 02130–3500, editor. 10. Owner: The Arnold Arboretum of Harvard University, 125 Arborway, Jamaica Plain, Suffolk County, MA 02130–3500. 11. Known Bondholders, Mortgagees, and Other Security Holders Owning or Holding 1 Percent or More of Total Amount of Bonds, Mortgages, or Other Securities: none. 12. The purpose, function, and nonprofit status of this organization and the exempt status for federal income tax purposes have not changed during the preceding 12 months. 13. Publication Name: *Arnoldia*. 14. Issue Date for Circulation Data Below: Summer 1998. 15. Extent and Nature of Circulation. a. Total No. Copies. Average No. Copies Each Issue During Preceding 12 Months: 4,450. Actual No. Copies of Single Issue Published Nearest to Filing Date: 4,500. b. Paid and/or Requested Circulation. (1) Sales Through Dealers and Carriers, Street Vendors, and Counter Sales. Average No. Copies Each Issue During Preceding 12 Months: 129. Actual No. Copies of Single Issue Published Nearest to Filing Date: 440. (2) Paid and/or Requested Mail Subscriptions. Average No. Copies Each Issue During Preceding 12 Months: 3,352. Actual No. Copies of Single Issue Published Nearest to Filing Date: 3,500. c. Total Paid and/or Requested Circulation. Average No. Copies Each Issue During Preceding 12 Months: 3,481. Actual No. Copies of Single Issue Published Nearest to Filing Date: 3,940. d. Free Distribution by Mail. Average No. Copies Each Issue During Preceding 12 Months: 187. Actual No. Copies of Single Issue Published Nearest to Filing Date: 175. e. Free Distribution Outside the Mail: Average No. Copies Each Issue During Preceding 12 Months: 230. Actual No. Copies of Single Issue Published Nearest to Filing Date: 325. f. Total Free Distribution: Average No. Copies Each Issue During Preceding 12 Months: 417. Actual No. Copies of Single Issue Published Nearest to Filing Date: 500. g. Total Distribution: Average No. Copies Each Issue During Preceding 12 Months: 3,898. Actual No. Copies of Single Issue Published Nearest to Filing Date: 4,440. h. Copies Not Distributed. (1) Office Use, Leftovers, Spoiled. Average No. Copies Each Issue During Preceding 12 Months: 650. Actual No. Copies of Single Issue Published Nearest to Filing Date: 235. (2) Return from news agents. Average No. Copies Each Issue During Preceding 12 Months: none. Actual No. Copies of Single Issue Published Nearest to Filing Date: none. i. Total. Average No. Copies Each Issue During Preceding 12 Months: 650. Actual No. Copies of Single Issue Published Nearest to Filing Date: 235. Percent Paid and/or Requested Circulation. Average No. Copies Each Issue During Preceding 12 Months: 85%. Actual No. Copies of Single Issue Published Nearest to Filing Date: 78%. I certify that all information furnished on this form is true and complete. Karen Madsen, Editor.